The effect of resin shades on microhardness, polymerization shrinkage, and color change of dental composite resins

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The present study sought to evaluate the effect of resin shades on the degree of the polymerization. To this end, response variables affected by the degree of polymerization were examined in this study — namely, microhardness, polymerization shrinkage, and color change. Two commercial composite resins of four different shades were employed in this study: shades A3, A3.5, B3, and C3 of Z250 (Z2) and shades A3, A3.5, B3, and B4 of Solitaire 2 (S2). After light curing, the reflectance/absorbance, microhardness, polymerization shrinkage, and color change of the specimens were measured. On reflectance and absorbance, Z2 and S2 showed similar distribution curves regardless of the resin shade, with shade A3.5 of Z2 and shade A3 of S2 exhibiting the lowest/highest distributions. Similarly for attenuation coefficient and microhardness, the lowest/highest values were exhibited by shade A3.5 of Z2 and shade A3 of S2. On polymerization shrinkage, no statistically significant differences were observed among the different shades of Z2. Similarly for color change, Z2 specimens exhibited only a slight (ΔE^*=0.5–0.9) color change after immersion in distilled water for 10 days, except for shades A3 and A3.5. Taken together, results of the present study suggested that the degree of polymerization of the tested composite resins was minimally affected by resin shade.

Keywords: Resin shade, Polymerization shrinkage, Color change

INTRODUCTION

Light-curing dental composite resins come in various shades to match the color of natural teeth so as to meet the increasing esthetic needs of patients and practitioners. To control the shades, pigments are used in conjunction with a yellow photoinitiator, camphorquinone, to modify the optical properties of the composite resins. Upon irradiation by a blue curing light, the light will be scattered by the distributed filler particles and pigments and absorbed by the photoinitiators and pigments. This means that as light passes through the composite resin, light intensity is attenuated, thereby resulting in reduced irradiance and curing effectiveness[1-4].

In light-curing composite resins, polymerization is initiated by the photoinitiator that absorbs the photons. During the polymerization process, carbon-carbon double bonds are broken to create carbon-carbon single bonds, thereby forming polymer networks. This means that during the polymerization process, the activated photoinitiator loses its yellowness and becomes invisible eventually[5]. For this reason, the initial CIE *b** (yellowness) value changes after polymerization[6,7].

Polymerized composite resins become hard after light curing. The hardness of a composite resin is an indirect indication of the quality of polymerization[8-11], and it is chiefly determined by the inorganic fillers and monomers included in the resins. In the subsurface, light curing proceeds by the transmitted light attenuated by filler and pigment particles. On the latter ground, the resin shade becomes an important factor as it affects the mechanical properties of light-cured composite resins[3,12,13].

In light-cured dental composite resins, polymerization shrinkage and contraction stress inevitably occur because of shortened molecular distance and the increase in volumetric shrinkage. Moreover, since most composite resins have diluent monomers blended with the base monomer, Bis-GMA, the density of the polymerizable carbon double bonds increases, which may lead to further shrinkage[14,15].

On resin shade, esthetic composite resins are typically manufactured in several shades, ranging from 6 to 48 for anterior use and from 6 to 20 for all-purpose use, depending on the brand[7]. Nonetheless, when esthetic composite resins are subjected to prolonged exposure to staining solutions in the oral environment, discoloration arising from a number of extrinsic and intrinsic factors can occur[16-20]. On this ground, the color stability of composite resins is an important factor in the selection of a resin product to the end of satisfying the esthetic needs of a patient.

The purpose of the present study was to investigate the effect of resin shade on the degree of polymerization in dental composite resins. To determine the extent to which resin shade would affect the degree of polymerization, it was accomplished by evaluating the microhardness, polymerization shrinkage, and color change of different shades of two commercial composite resins.

MATERIALS AND METHODS

Light-curing dental composite resins
In this study, different shades of two light-curing dental composite resins were selected for investigation. They were namely shades A3, A3.5, B3, and C3 of Z250

Table 1   Details of the composite resins tested in this study

| | Composition | Filler type | Filler content* | | Batch | Company |
			vol%	wt%		
Z2	Bis-GMA, Bis-EMA, UDMA	Zirconia/silica	60	82	3LBJ	3M ESPE
S2	Bis-GMA, HPMA, ETMA, PENTA	Ba-Al-F glass, Ba glass, porous SiO_2	58	75	050236	Heraeus Kulzer

Z2: Z250; S2: Solitaire 2
Bis-GMA: Bisphenol glycidylmethacrylate; Bis-EMA: Ethoxylated bisphenol A dimethacrylate;
UDMA: Urethane dimethacrylate; HPMA: 3-hydroxypropyl methacrylate;
ETMA: Ethyltriglycol methacrylate; PENTA: pentaerythrytol tetraacrylate
*: According to the manufacturers

(Z2) and shades A3, A3.5, B3, and B4 of Solitaire 2 (S2). Their details are listed in Table 1.

Photon attenuation coefficient measurement
For light curing, a quartz-tungsten-halogen (QTH) light curing unit (Optilux 501, Kerr, Dansbury, CT, USA) was used in this study. Its emission spectrum was measured using a photodiode array detector (M1420, EG&G PARC, Princeton, NJ, USA) connected to a spectrometer (SpectroPro-500, Acton Research, Acton, MA, USA). Output light intensity was 1100 mW/cm² according to a radiometer. Specimen was irradiated with the end of the light guide in contact with its top surface.

To measure the numbers of photons transmitted through the composite resin specimens of different thicknesses and shades, the abovementioned photodiode detector and spectrometer were employed. Light-cured specimens of different thicknesses and shades were placed over a stage with a 6.8-mm-diameter hole. Under this hole, the photodiode detector was placed in a fixed position to count the photons.

Reflectance (%R) and absorbance measurements
To measure the reflectance/absorbance of the composite resin specimens, a Teflon (polytetrafluoroethylene, PTFE) disk was used. The baseline of the UV-VIS-NIR spectrophotometer (CARY 5G, Varian, Victoria, Australia) was calibrated by measuring the reflectance/absorbance of the Teflon disk from 380 to 780 nm. A Teflon disk was chosen as the specimen holder because it could be used to coat the inside of the integrating sphere of the spectrophotometer.

Composite resin was filled into a cylindrical acrylic ring mold (inner diameter: 7 mm, height: 2 mm) and light-cured for 40 seconds under 1100 mW/cm² light intensity. Light-cured specimen was then plugged into a hole at the center of the Teflon disk, whereby the diameter and depth of the hole were 7.1 mm and 0.5 mm respectively. Such a hole served to maintain the consistency of specimen placement at the center of the disk during measurements.

Microhardness measurement
To measure the surface microhardness of the composite

resin specimens, resin was filled into a metal mold (4×2×3 mm), light-cured for 40 seconds using the QTH light curing unit, and then removed form the mold. Diameter of the light guide was 8 mm. After aging for 24 hours in a dark chamber, the microhardness of the top (z=0 mm), lateral (z=1 and 2 mm), and bottom (z=3 mm) surfaces were measured using a Vickers hardness tester (MVK-H1, Akashi Co., Tokyo, Japan). Microindentations (n=12 for each test condition) were made on each surface under a 200-gf load with a 10-second dwell time.

Polymerization shrinkage measurement
To measure polymerization shrinkage (n=5) during the light curing process, a linometer (RB 404, R&B Inc., Daejon, Korea) was used. This system comprised a specimen holder, a curing light, a shrinkage sensor, software, and a computer. On the specimen holder, composite resin was filled into a Teflon mold (inner diameter: 4 mm, height: 1, 2, and 3 mm) which was placed over an aluminum disk. To facilitate polymerization shrinkage measurement, the disk was slightly coated with Vaseline. After being filled completely with resin, the Teflon mold was removed.

A glass slide was then placed over the composite resin specimen. The probe of the light curing unit was in contact with the glass slide. Before light curing, the initial position of the aluminum disk was set at zero. During the light curing process, the composite resin specimen shrank toward the light source. Concomitantly, the aluminum disk under the composite resin specimen also moved toward the light source. The amount of disk displacement which occurred due to polymerization shrinkage was automatically measured by a non-contacting inductive gage for 300 seconds. The shrinkage sensor used in this study was a non-contacting type with a resolution of 0.1 μm and a measurement range of 100 μm.

Color change measurement
To evaluate color change, previously reflectance-measured specimens (n=5 for each shade) were immersed in distilled water at 37°C for 10 days. The distilled water used for immersion was replaced every two days. After 10 days, the specimens were removed

from the immersion solution and rinsed under running water. After removing any water which remained on the surface with a tissue paper, the specimen was plugged into the hole at the center of Teflon disk and its reflectance measured again.

Based on the measured reflectance data, the color values on the CIE $L*a*b*$ color coordinate system were evaluated using an internal software of the measurement system. The color difference $\Delta E*$ was obtained using the following equation:

$$\Delta E* = [(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]^{1/2}$$

where $\Delta L*$, $\Delta a*$, and $\Delta b*$ are the changes in $L*$, $a*$, and $b*$ respectively. Here, $L*$ represents the degree of grayness and corresponds to lightness. The parameter $a*$ represents the red (for $+a*$ value) - green (for $-a*$ value) axis, whereas $b*$ is a parameter in the blue (for $-b*$ value) - yellow (for $+b*$ value) axis.
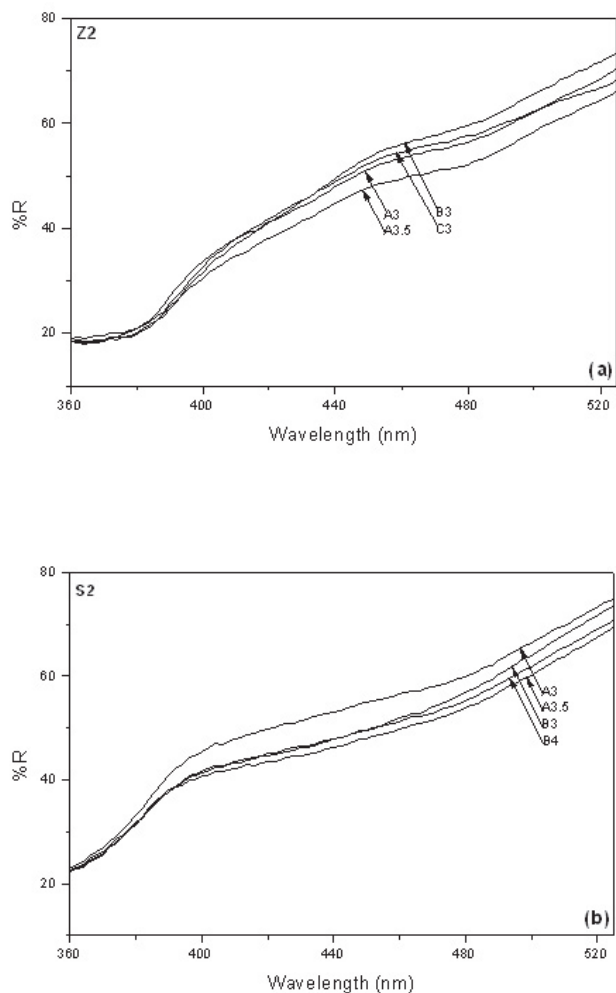
Statistical analysis
Results from microhardness and polymerization shrinkage measurements were analyzed using two-way ANOVA for shade and depth (thickness). A Tukey's test then followed the multiple comparison procedure. All results were analyzed at $p<0.05$.

RESULTS

Reflectance and absorbance
Figure 1 shows the reflectance (%R) distributions of the composite resin specimens (Z2 and S2) of different shades used in this study. Similar reflectance distributions were observed despite differences in resin shade and product. At 400–440 nm, Z2 showed a slightly lower reflectance distribution than S2.

Figure 2 shows the absorbance distributions of the different shades of Z2 and S2 specimens as well as the emission spectrum of the light curing unit used in this study. Similar absorbance distributions were observed

Fig. 1 Reflectance (%) distributions of (a) Z2 and (b) S2 of different shades.
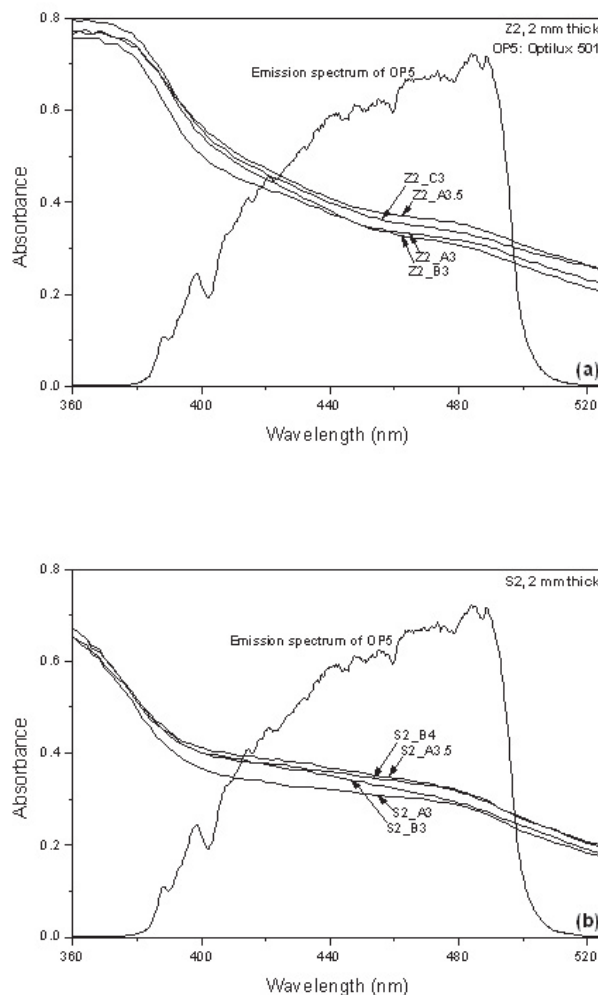

Fig. 2 Absorbance distributions of (a) Z2 and (b) S2 of different shades and the emission spectrum of the light curing unit.

regardless of resin shade. At 400–440 nm, Z2 showed a slightly higher absorbance distribution than S2. However, as the wavelength increased, the absorbance gradually decreased. Within each resin product, shade A3.5 of Z2 and shade A3 of S2 exhibited the highest and lowest absorbance distributions respectively.

Table 2 shows the CIE $L*a*b*$ values of the composite resin specimens. Within each resin product, different shades had different $L*$, $a*$, and $b*$ values.

On the other hand, for the same shade, similar $L*$, $a*$, and $b*$ values were observed for the different resin products.

Number of detected photons and attenuation coefficient
The numbers of photons detected with and without the composite resin specimens and the estimated attenuation coefficients (mm^{-1}) based on the detected photons are shown in Table 3. The number of incident

Table 2   CIE $L*a*b*$ values for the different shades of the two tested composite resins

	Shade	$L*$	$a*$	$b*$
	A3	92.44 ± 0.23	8.11 ± 0.10	25.04 ± 0.18
	A3.5	90.74 ± 0.20	8.98 ± 0.13	25.96 ± 0.15
Z2	B3	92.54 ± 0.19	5.51 ± 0.12	22.91 ± 0.23
	C3	89.58 ± 0.26	5.58 ± 0.18	19.27 ± 0.27
	A3	93.67 ± 0.28	6.69 ± 0.17	22.86 ± 0.21
	A3.5	91.78 ± 0.19	7.94 ± 0.20	26.13 ± 0.26
S2	B3	93.38 ± 0.21	6.81 ± 0.14	26.56 ± 0.18
	B4	92.22 ± 0.24	7.60 ± 0.18	25.30 ± 0.29

Table 3   Detected photons from the light curing unit and the estimated attenuation coefficients (mm^{-1}) of the incident photons

		No specimen	1 mm	2 mm	3 mm	AC (mm^{-1})	R^2
	A3		3603 ± 214	1165 ± 103	628 ± 63	1.12	0.97
	A3.5		3001 ± 265	936 ± 86	348 ± 28	1.29	0.99
Z2	B3		3129 ± 240	1078 ± 98	477 ± 40	1.21	0.98
	C3	13942 ± 259	3436 ± 285	1276 ± 109	616 ± 49	1.11	0.97
	A3		3350 ± 263	1085 ± 87	386 ± 23	1.23	0.99
	A3.5		2138 ± 209	618 ± 51	253 ± 19	1.44	0.96
S2	B3		2667 ± 202	924 ± 78	337 ± 28	1.30	0.98
	B4		2500 ± 198	708 ± 49	254 ± 20	1.41	0.98

AC: Attenuation coefficient
R^2: correlation coefficient

Table 4   Microhardness (HV) changes for the different shades

		Microhardness (HV)				
		Position from top surface to base (mm)				
	Shade	0[1]	1[2]	2[3]	3[4]	*p*-Values
	A3[A]	90.6 ± 1.2	87.9 ± 1.1	84.4 ± 1.0	76.9 ± 1.8	
	A3.5[B]	83.8 ± 1.3	80.8 ± 1.6	78.0 ± 0.9	69.6 ± 1.2	α<0.0001
Z2	B3[C]	87.0 ± 1.1	82.7 ± 1.6	78.3 ± 1.9	77.3 ± 1.1	β<0.0001
	C3[C]	86.2 ± 1.3	83.4 ± 1.3	78.5 ± 1.6	78.0 ± 1.1	
		0[1]	1[2]	2[3]	3[4]	
	A3[A]	56.0 ± 1.5	45.2 ± 1.2	37.4 ± 2.7	34.8 ± 1.7	
	A3.5[BC]	55.9 ± 1.7	43.0 ± 1.6	34.5 ± 1.6	22.0 ± 1.6	α<0.0001
S2	B3[B]	55.2 ± 1.1	44.6 ± 1.2	34.7 ± 2.0	25.7 ± 1.3	β<0.0001
	B4[C]	53.5 ± 1.1	44.5 ± 0.8	33.9 ± 1.1	24.7 ± 0.9	

* Statistically significant difference on shade is shown by superscript letters[A, B, C], on depth by superscript numbers[1, 2, 3]. Same letters or numbers are not significantly different (*p*>0.05).
* On *p*-values, the letters α and β denote shade and depth respectively.

Table 5   Maximum polymerization shrinkage values (μm) for the different shades and thicknesses of the two tested composite resins

	Shade	Polymerization shrinkage (μm)			
		Specimen thickness (mm)			
	Shade	1^1	2^2	3^3	p-values
Z2	A3[A]	16.0 ± 0.3	17.9 ± 0.4	19.3 ± 0.8	
	A3.5[A]	16.6 ± 0.2	18.0 ± 0.3	19.1 ± 0.8	α<0.0001
	B3[A]	16.5 ± 0.4	17.4 ± 0.6	20.2 ± 0.3	β<0.0001
	C3[A]	16.6 ± 0.3	18.0 ± 0.3	20.1 ± 0.7	
	Shade	1^1	2^2	3^2	p-values
S2	A3[AC]	25.0 ± 0.8	31.3 ± 0.8	31.5 ± 0.9	
	A3.5[B]	26.0 ± 0.9	30.0 ± 1.0	28.5 ± 0.6	α<0.0001
	B[C]	27.2 ± 0.4	30.7 ± 1.2	31.2 ± 0.8	β<0.0001
	B4[AB]	26.3 ± 0.4	29.0 ± 1.0	30.7 ± 1.5	

* Statistically significant difference on shade is shown by superscript letters[A, B, C], on depth by superscript numbers[1, 2, 3]. Same letters or numbers are not significantly different (p>0.05).
* On p-values, the letters α and β denote shade and depth respectively.

photons decreased exponentially as the thickness of the specimen increased. With Z2, shade A3.5 showed the highest attenuation coefficient (1.29). With S2, shade A3 showed the lowest attenuation coefficient (1.23).

Microhardness
Table 4 shows the microhardness changes in the specimens of different shades at different depths. Z2 exhibited much higher microhardness values than S2 for all the shades.

With Z2, shade A3.5 exhibited the lowest microhardness values at all depths. In addition, shades B3 and C3 showed statistically similar microhardness values.

Conversely, with S2, shade A3 exhibited the highest microhardness values at all depths. As a result, the microhardness values of shade A3 were statistically different from the other shades.

Polymerization shrinkage
Table 5 shows the maximum polymerization shrinkage values of the specimens for different shades and thicknesses. With Z2, no statistically significant differences in polymerization shrinkage were observed among the different shades. On the overall, Z2 specimens shrank from 16 to 20 μm depending on the thickness of the specimens. Compared to Z2, S2 specimens exhibited higher polymerization shrinkage. Further, polymerization shrinkage in S2 specimens was slightly affected by shade differences.

Color change
Table 6 shows the color differences (ΔE^*) in the specimens of different shades after immersion in distilled water for 10 days. With Z2, the specimens showed a slight (0.5–0.9) color change regardless of the shade, except for shades A3 and A3.5.

Table 6   Color difference (ΔE^*) values for the different shades after immersion in distilled water for 10 days

	Shade	ΔE^*
Z2	A3	2.3 ± 0.2
	A3.5	2.2 ± 0.2
	B3	0.9 ± 0.1
	C3	0.9 ± 0.1
S2	A3	0.5 ± 0.0
	A3.5	0.7 ± 0.0
	B3	0.8 ± 0.2
	B4	0.8 ± 0.1

DISCUSSION

Reflectance and absorbance
During dental restoration, a good understanding of the reflectance (%R) of resin products of various shades will greatly enable the selection of an optimal shade match to the existing natural teeth. In the present study, the two tested resin products showed similar reflectance distributions within each product regardless of differences in resin shade. On the other hand, for the same shade, different reflectance distributions were found for the two resin products. It was probable that differences in pigment type and content affected the reflectance distribution of each shade in each product.

Based on the CIE $L^*a^*b^*$ values (Table 2), a meaningful difference could be gleaned from the b^* value. Shade C3 of Z2 and shade A3 of S2 showed the lowest b^* (yellowness) value after the specimens were light-cured. In light-curing dental materials, the yellowness was controlled by the content of camphorquinone (CQ), a yellow photoinitiator. Since CQ is activated by blue light, the change in b^* after

light curing was most probably related to the activation of CQ[6,21]. Since CQ becomes invisible after polymerization is completed, a lower $b*$ value would thus cement the notion of the specimens undergoing polymerization[5].

Regardless of resin shade, the two composite resins tested had a similar but decreasing absorbance pattern as the wavelength increased. A higher absorbance means a lower transmission of curing light through the specimen. Conversely, assuming that all other resin conditions are identical except for the shade, a lower absorbance would better serve the purpose of polymerization. As seen in Fig. 2, shade A3.5 of Z2 and shade A3 of S2 consistently exhibited the highest and lowest absorbance distributions respectively. However, at 460–470 nm, near the emission peak of the light curing unit, specimens showed a similar absorbance (transmittance) range despite differences in resin shade.

Number of detected photons and attenuation coefficient
To activate the photoinitiator, it is important that sufficient photons are emitted from the light curing unit — for the number of photons emitted correlates with the incident light intensity. Generally, irradiation with a curing light of 400 mW/cm² intensity for 40 seconds is sufficient to cure composite resins of 2 mm thickness[8]. As curing light passes through the bulk of a resin composite, its intensity decreases exponentially. This decrease can be characterized by the Beer–Lambert law, $I = I_0 \cdot e^{-\alpha z}$, where I_0 is the intensity of the incident light, α is the attenuation coefficient, and z is the position in the subsurface[2,3].

Within the same resin product, monomer composition and filler content may be the same regardless of differences in resin shade. In other words, the attenuation coefficient is determined and controlled by the type and content of pigment used in a resin product[22,23]. With Z2, different attenuation coefficient values were shown for the different shades. In particular, shades C3 and A3.5 showed the lowest and highest attenuation coefficient values respectively (Table 3). This meant that shades C3 and A3.5 could transmit the highest and lowest numbers of photons to the bottom surface respectively. By the same token, shades A3 and A3.5 of S2 could transmit the highest and lowest numbers of photons to the bottom surface respectively.

Microhardness
The shade of a composite resin is a key factor in the number of photons arriving at its bottom surface, and the number of photons detected affects the microhardness. With Z2, shade A3.5 exhibited the lowest microhardness values at all depths — which could be explained by its highest absorbance distribution. As for the lowest microhardness value at z=3 mm, it could be readily explained by the lowest number of photons detected.

With S2, the number of photons detected drastically decreased from the top surface (z=0) to z=1 mm when compared to Z2. As a result, regardless of resin shade, the microhardness values of S2 were lower than those of Z2 at z=1 mm when compared to the top surface (z=0). In addition, shades A3 and A3.5 of S2 exhibited the highest and lowest microhardness values respectively due to the availability of photons for polymerization at z=3 mm.

Polymerization shrinkage
At all specimen thicknesses, statistically significant differences in maximum polymerization shrinkage were observed between the same shade of the two resin products and among the different shades within the same resin product.

Polymerization shrinkage is an inevitable outcome of the polymerization process. The van der Waals forces that hold the molecules together convert to covalent bonds, and such conversion is simultaneously accompanied by reductions in molecular distance and free volume. These reductions bring about polymerization shrinkage, which then produces a stress in resin composites during curing. Several causative factors for polymerization shrinkage have been identified, amongst which are several material formulation factors such as filler content, monomer chemistry, monomer structure, and additives[14]. Similarly, material polymerization factors that have been identified to affect polymerization shrinkage are namely the curing method, placement technique, and catalyst and inhibitor concentration[14]. Amongst these factors, the filler content (in other words, the monomer content) is directly correlated with polymerization shrinkage and contraction stress in dental composite materials[24].

The two resin products tested had similar filler contents (60 and 58 vol% for Z2 and S2 respectively). However, if the contents of their microfiller particles (less than 100 nm) were different (the exact microfiller contents of the two tested products were not known at the time of writing), it might result in differing degrees of polymerization shrinkage. Microfillers provide a very large surface area-to-volume ratio and have extensive possibilities to interact with the resin matrix. Consequently, constraining the molecular mobility at the filler-matrix interface during polymerization will bring about a decrease in polymerization shrinkage[25].

Apart from filler content, monomer formulation and monomer content also affect polymerization shrinkage. It has been reported that shrinkage values for Bis-GMA (5.2%) and TEGDMA (12.5%) are substantially higher than those displayed by typical composite resins[26-28]. In most commercial composite resins, the base monomer used, Bis-GMA, has very high viscosity. Such high viscosity can be lowered by adding lower molecular weight diluents, TEGDMA and UDMA, to render the composite resins more workable for the practitioners. However, the added diluent monomers increase the density of polymerizable carbon double bonds and may lead to more shrinkage. In the

present study, the exact contents of the included diluents for the two tested resin products were not known. However, it was hypothesized that the higher shrinkage in S2 was related to its higher diluent content. Moreover, this hypothesis could find further support in S2 being softer than Z2 at room temperature, thereby indicating a higher diluent content in S2.

On the influence of resin shade on polymerization shrinkage, results in Table 5 indicated that the pigments included in Z2 had no significant influence on its shrinkage values. With S2, a significant influence could be discerned, but the differences thereof among the different shades were minimal.

Color change
The discoloration of a composite resin is affected by a number of factors such as chemical reactivity, exposure to various energy sources, water sorption, diet, and surface smoothness of the restoration[16-20]. In the present study, all the aforementioned factors were not investigated except for immersion in water. The susceptibility to color change in restorative dental composite resins is most probably related to the degree of water sorption and hydrophilicity of the resin matrix. Among the monomers commonly used in dental composite resins, water sorption decreases in the following order: TEGDMA>Bis-GMA>UDMA. These monomers have hydrophilic ether linkages (TEGDMA), hydroxyl groups (Bis-GMA), and urethane linkages (UDMA). Bis-EMA (ethoxylated Bis-GMA) has low water sorption ability because it does not contain the hydroxyl group[29]. As for the other monomers in S2, there were no reported data on their water sorption behaviors.

Once water enters the polymer network through porosity or intermolecular spaces, the resin matrix swells and the unpolymerized resin components elute, thereby degrading some of the polymer networks. Since water can erode the surface of filler particles, it may also change the surface smoothness[30,31]. Besides, water can dilute the pigments in restorative dental composite materials. In the present study, shades A3 and A3.5 of Z2 showed a noticeable (ΔE^*=2.2 and 2.3) color change, whereas the other shades of Z2 and S2 showed a slight (ΔE^*=0.5–0.9) color change after a 10-day immersion in distilled water. Therefore, regardless of resin shade, the extents of color change in the tested resin products could be rated as acceptable[16].

CONCLUSIONS

The effect of resin shades on polymerization was investigated. Within the limits of the present study, specimens within the same product showed similar reflectance distributions despite differences in resin shade. Between the two products, specimens of the same shade had similar *L**, *a**, and *b** values. However, shade difference and attenuation coefficient of the incident photons were not consistently correlated.

Nonetheless, since shade A3.5 of Z2 and shade A3 of S2 showed the highest and lowest absorbance distributions respectively, their microhardness values were the lowest and highest correspondingly within their respective products. On color change, a slight discoloration was observed for both products regardless of resin shade.

Notwithstanding the differences in data obtained for both products, the macroscopic conclusion of this study was that resin shades had minimal effect on microhardness, polymerization shrinkage, and color change on the tested composite resins. Therefore, choice of a specific shade for a dental restoration hinges only on the closest shade match with the existing natural teeth, without undue concerns about its effect on degree of polymerization.

ACKNOWLEDGMENTS

REFERENCES

1) Ruyter IE, Oysaed H. Conversion in different depths of ultraviolet and visible light activated composite materials. Acta Odontol Scand 1982; 40: 179-192.
2) McCabe JF, Carrick TE. Output from visible-light activation units and depth of cure of light-activated composites. J Dent Res 1989; 68: 1534-1539.
3) Kawaguchi M, Fukushima T, Miyazaki K. The relationship between cure depth and transmission coefficient of visible-light-activated resin composites. J Dent Res 1994; 73: 516-521.
4) Watts DC, Cash AJ. Analysis of optical transmission dental materials by 400–500nm visible light into aesthetic dental biomaterials. J Dent 1994; 22: 112-117.
5) Taira M, Urabe H, Hirose T, Wakasa K, Yamaki M. Analysis of photo-initiators in visible-light-cured dental composite resins. J Dent Res 1988; 67: 24-28.
6) Seghi RR, Gritz MD, Kim J. Colorimetric changes in composites resulting from visible-light-initiated polymerization. Dent Mater 1990; 6: 133-137.
7) Uchida H, Vaidyanathan J, Viswanadhan T, Vaidyanathan TK. Color stability of dental composites as a function of shade. J Prosthet Dent 1998; 79: 372-377.
8) Rueggeberg FA, Ergle JW, Mettenburg DJ. Polymerization depths of contemporary light-curing units using microhardness. J Esthet Dent 2000; 12: 340-349.
9) Park SH, Krejci I, Lutz F. Microhardness of resin composites polymerized by plasma arc or conventional visible light curing. Oper Dent 2002; 27: 30-37.
10) Aguiar FH, Braceiro AT, Ambrosano GM, Lovadino JR. Hardness and diametral tensile strength of a hybrid composite resin polymerized with different modes and immersed in ethanol or distilled water media. Dent Mater 2005; 21: 1098-1103.
11) Kwon YH, Jeon GH, Jang CM, Seol HJ, Kim HI. Evaluation of polymerization of light-curing hybrid composite resins. J Biomed Mater Res B Appl Biomater 2006; 76: 106-113.
12) Arikawa H, Fujii K, Kanie T, Inoue K. Light transmittance characteristics of light-cured composite resins. Dent Mater 1998; 14: 405-411.
13) Cesar PF, Miranda WG Jr, Braga RR. Influence of shade and storage time on the flexural strength, flexural modulus,

and hardness of composites used for indirect restorations. J Prosthet Dent 2001; 86: 289-296.

14) Ferracane JL. Developing a more complete understanding of stresses produced in dental composites during polymerization. Dent Mater 2005; 21: 36-42.

15) Braga RR, Ballester RY, Ferracane JL. Factors involved in the development of polymerization shrinkage stress in resin-composites: A systematic review. Dent Mater 2005; 21: 962-970.

16) Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. Quintessence Int 1991; 22: 377-386.

17) Lang R, Rosentritt M, Leibrock A, Behr M, Handel G. Color stability of provisional crown and bridge restoration materials. Br Dent J 1998; 185: 468-471.

18) Koishi Y, Tanoue N, Matsumura H, Atsuta M. Color reproducibility of a photo-activated prosthetic composite with different thicknesses. J Oral Rehabil 2001; 28: 799-804.

19) Sen D, Goller G, Issever H. The effect of two polishing pastes on the surface roughness of bis-acryl composite and methacrylate-based resins. J Prosthet Dent 2002; 88: 527-532.

20) Eliades T, Gioka C, Heim M, Eliades G, Makou M. Color stability of orthodontic adhesive resins. Angle Orthod 2004; 74: 391-393.

21) Shortall AC. How light source and product shade influence cure depth for a contemporary composite. J Oral Rehabil 2005; 32: 906-911.

22) Ruyter IE. Composites — characterization of composite filling materials: reactor response. Adv Dent Res 1988; 2: 122-129.

23) von Fraunhofer JA, Curtis P. The physical and mechanical properties of anterior and posterior composite restorative materials. Dent Mater 1989; 5: 365-368.

24) Condon JR, Ferracane JL. Assessing the effect of composite formulation on polymerization stress. J Am Dent Assoc 2000; 131: 497-503.

25) Condon JR, Ferracane JL. Reduction of composite contraction stress through non-bonded microfiller particles. Dent Mater 1998; 14: 256-260.

26) Stansbury JW. Cyclopolymerizable monomers for use in dental resin composites. J Dent Res 1990; 69: 844-848.

27) Stansbury JW. Synthesis and evaluation of novel multifunctional oligomers for dentistry. J Dent Res 1992; 71: 434-437.

28) Labella R, Lambrechts P, Van Meerbeek B, Vanherle G. Polymerization shrinkage and elasticity of flowable composites and filled adhesives. Dent Mater 1999; 15: 128-137.

29) Sideridou I, Tserki V, Papanastasiou G. Study of water sorption, solubility and modulus of blue light differentially modulates cell survival and growth. J Dent Res 2004; 83: 104-108.

30) Shintani H, Satou J, Satou N, Hayashihara H, Inoue T. Effects of various finishing methods on staining and accumulation of streptococcus mutans HS-6 on composite resins. Dent Mater 1985; 1: 225-227.

31) Reis AF, Giannini M, Lovadino JR, Ambrosano GM. Effects of various finishing systems on the surface roughness and staining susceptibility of packable composite resins. Dent Mater 2003; 19: 12-18.