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Original research

Effect of light guide tip diameter on the degree of conversion and depth of cure of bulk-fill composites

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Purpose
This study aimed to evaluate the effects of the light guide tip diameter on the degree of conversion, micro-hardness, and depth of cure of bulk-fill composites compared to a conventional composite.

Materials and Methods
Layers of Tetric EvoCeram (2 mm), Tetric EvoCeram Bulk Fill (4 mm), SonicFill 2 (5 mm) were placed in 4 mm diameter molds and were cured with LED light curing unit having 13/8 or 13/4 mm diameter turbo light guide tips for 10 s with a total number of 60 samples (n=5). Then, specimens were stored in a dark and dry environment at 37°C for 24 h, and Vickers micro-hardness values of the top and bottom surfaces of 30 specimens were measured. The other 30 specimens were pulverized, and the degree of conversion values of the specimens was measured with FTIR-ATR. The depth of cure was determined by proportioning the bottom surface's micro-hardness value to the top surfaces. Data were analyzed with the Shapiro-Wilks test, Student's t-test, and Pearson's correlation analysis ($p < 0.05$).

Results
The degree of conversion and the depth of cure of bulk-fill composites cured with 13/8 mm diameter tip were higher than those cured with 13/4 mm diameter tip ($p<0.01$). The degree of conversion of the bulk-fill composites applied in the layer thickness recommended by the manufacturer was below the clinically accepted rate of 55%, and the depth of cure remained below 80%.

Conclusion
The curing of bulk-fill composites with light guide tips of different diameters affects the degree of conversion and the depth of the cure.

Keywords: *Bulk-fill composite, degree of conversion, depth of cure, light-guide tip diameter, micro-hardness*

Introduction

Despite all the improvements in composite resins, polymerization still needs to be improved. To ensure adequate polymerization, the applied light should penetrate down to the base of the composite. However, the applied light energy decreases through the deep layers of the composite, and polymerization of the bottom that the light does not reach sufficiently is inadequate (1). Inadequate polymerization weakens composite resins' physical, mechanical, and biological properties (2, 3). For adequate polymerization, the monomers in the organic matrix must be converted to polymers at the highest rate (4). A high degree of conversion (DC) is significant for the material's chemical stability and the restoration's clinical longevity (5). A low DC weakens the material's physical properties, causing an increase in residual monomer that adversely affects the pulp tissue, causing discoloration and failures in the restoration (6).

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For conventional composites to be sufficiently polymerized, they should be applied to a cavity with a thickness of up to 2 mm (5). This application, which requires technical precision, requires much time, especially in deep cavities, and makes the application more complicated (3). Bulk-fill composites developed to eliminate these problems can be applied to the cavity in thicker layers (2), and this application not only saves time for the dental professional but also prevents void incorporation and contamination between layers, allowing for more successful restorations (3, 7). Different applications are available to increase light transmission to ensure that bulk-fill composites are polymerized in thicker layers than conventional composites. One of these applications is using an increased size of the inorganic fillers to reduce the surface area between the organic matrix and the fillers. Thus, by increasing the material's translucency, the scattering of the light applied from the surface decreases as it moves toward the bottom, and a deeper polymerization is provided (1).

Low-viscosity bulk-fill composites have a flowable consistency because less filler is used. Thus, it adapts to cavity walls more easily. Since the mechanical properties of low-viscosity bulk-fill composites are weak, the occlusal surfaces must be covered with conventional composites. However, the entire cavity can be restored with high-viscosity bulk-fill composites (8). A sonic activation device is used to facilitate the flowability of some high-viscosity bulk-fill composites and better adapt to the cavity walls (9).

The fact that the light guide tips have different diameters and geometric structures causes the intensity and scattering of the transmitted light to be different, and this affects the polymerization of the composite (10,11). The standard light guide tips are in parallel structures, and the diameter of the tip is the same at the entry and exit points of the light, while the tip ends narrow in the turbo tips. This way, the light power is concentrated in a smaller area, and a denser light is applied to the restoration surface. However, since the scattering of light is greater at the turbo tips, the intensity in the deep layers decreases more than at the standard tip (11). Although many studies have been conducted to evaluate the DC and micro-hardness of bulk-fill composites (1-5,7,8,12), there are few studies in the literature about the effect of light guide tips of different diameters on DC, micro-hardness, and DOC of bulk-fill materials (13-17).

This study aims to evaluate the effects of light guide tip diameter on DC, micro-hardness, and the DOC of light-cured bulk-fill composites compared to a conventional composite. This study hypothesizes that using light guide tips of different diameters does not affect the DC and DOC of light-cured bulk-fill composites.

Materials and Methods

Sample size estimation

The main hypothesis of the research was to compare two independent groups. Similar studies that can be used in the sample size calculation were examined, and the highest sample size calculation was based on the statistical method according to the hypotheses. In this study, the sample size was calculated at the 95% confidence level by using the "G-Power 3.1.9.2" program (Universitat Kiel, Germany) (18). As a result of the analysis, α=0.05, the standardized effect size from the previous study comparing two independent groups (4.55±0.01, 4.60±0.03) (11), was calculated as 2.2360 and with theoretical power of 0.80, the minimum sample size was calculated as 10. Thus, a minimum sample size of 5 per group was calculated.

Sample preparation

Two commercially available bulk-fill composites, Tetric EvoCeram Bulk Fill (TECBF) (Ivoclar, Vivadent, Schaan, Liechtenstein), SonicFill 2 (SF) (Kerr Corp. Orange, CA, USA), and a conventional composite, Tetric EvoCeram (TEC) (control group) (Ivoclar, Vivadent, Schaan, Liechtenstein), were the materials under investigation (Table 1). A total of 60 samples (n = 5) with a diameter of 4 mm were prepared. The sam-

Table 1. *Characteristics of the composite filling materials used in the study.*

Material	Manufacturer, batch no.	Curing time	Type (shade, max. layer thickness)	Resin Composition (Filler wt/vol%)	Filler Size
Tetric EvoCeram (TEC) (control group)	Ivoclar Vivadent, Schaan, Liechtenstein, U23115	10 s	Conventional sculptable, (A2, 2 mm)	Resin matrix:Bis-GMA, Bis-EMA, UDMA Filler: Barium glass, YbF3, mixed oxide, PPF (75-76%/53-55%)	0,04-3µm
Tetric EvoCeram Bulk Fill (TECBF)	Ivoclar Vivadent Schaan, Liechtenstein, U17294	10 s	Sculptable full-depth bulk-fill/ no capping layer required (IVA, 4 mm)	Resin matrix:Bis-GMA, Bis-EMA, UDMA Filler: Barium glass, YbF3, mixed oxide, PPF (76-77% /53-54%)	0,04-3µm
SonicFill 2 (SF)	Kerr Corp. Orange, CA, USA, 6038935	10 s	Sonic-activated flowable and sculptable full-depth bulk-fill/ no capping layer required (A2, 5 mm)	Resin matrix:Bis-GMA, TEGDMA, Bis-EMA, Bis-EMA SR-541 / Filler: Glass, SiO2, oxide, PPF zirkonium silicate (81,5%/65,9%)	4µm

Bis-GMA, Bisphenol-A glycidyl methacrylate, TEGDMA, Triethyleneglycol dimethacrylate; UDMA, Urethane dimethacrylate; Bis-EMA, Ethoxylated Bisphenol A dimethacrylate; PPF, prepolymerized fillers; YbF_3, ytterbium trifluoride

ple thickness was 2 mm for TEC, 4 mm for TECBF, and 5 mm for SF, adhering to the maximum DOC recommended by the manufacturer. Composite resins were placed in a Delrin mold, which was placed on a glass slide. Then, the samples were covered with clear tape (Mylar Strip; SS White, Philadelphia, PA, USA) and 1 mm-thick microscope glass. The samples were polymerized with a Demi Plus (Kerr Corp. Orange, CA, USA) light-curing unit at a wavelength of 450–470 nm, employing periodic level shifting technology, which shifts the output intensity from 1,100 mW/cm^2 to a peak of 1,330 mW/cm^2 multiple times throughout the curing cycle. Half of each composite was cured with a light guide tip in a turbo geometry with a diameter of 13 mm at the entry point of the light to the optical tip and 8 mm at the point of exit from the tip (13/8). The other half was cured with a light guide tip in a turbo geometry with a diameter of 13 mm at the light entry point into the optical tip and 4 mm at the exit from the tip (13/4). Each group was cured for 10 sec according to the manufacturer's recommendation. The samples were kept in a dark environment at 37 ℃ for 24 hours to complete the polymerization reactions. The samples were then divided into two subgroups to make the necessary preparations for measuring DC and micro-hardness.

Degree of conversion measurements

The DC of the composite samples (n = 5) was determined by FTIR spectroscopy (Shimadzu IR Prestige21, Shimadzu Co. Japan) equipped with an attenuated total reflectance (ATR) unit. The sample diameter was 4 mm, and the thickness was 2 mm for TEC, 4 mm for TECBF, and 5 mm for SF. First, unpolymerized restorative material was placed on the ATR crystal of the device, and the FTIR spectra of the uncured samples were then collected. The cured composite samples were ground into a powder using a pestle and mortar. Three measurements were made for each specimen. Each specimen was measured with 16 scans at a resolution of 4 cm^{-1} within a wavelength spectrum of 4000–600 cm^{-1}. Peak heights at 1637 cm^{-1} (aliphatic carbon double bonds) and 1608 cm^{-1} (aromatic carbon double bonds) were measured using the baseline method with Origin 8.6 software (Origin, Massachusetts, USA). The DC was calculated according to the following formula: %DC = 100- [(AD/BC) x 100], where A: Absorption values of C=C groups at 1637 cm^{-1} in polymerized samples, B: Absorption values of aromatic groups at 1608 cm^{-1} in polymerized samples, C: Absorption values of C=C groups at 1637 cm^{-1} of unpolymerized samples, D: Absorption values of aromatic groups at 1608 cm^{-1} in unpolymerized samples.

Vickers micro-hardness was determined with the Vickers micro-hardness (Innovatest Maastricht, Nederland) device

For the micro-hardness test, the upper surfaces of the samples (n = 5) were polished with four different grains of polishing disks (Optidisc, Kerr USA) containing aluminum oxide particles at low speed for 10 sec. Vickers micro-hardness was determined with the Vickers micro-hardness (Innovatest Maastricht, Nederland) device. A constant load of 300 g was applied for 15 sec on the top and bottom surfaces of the samples, and three traces were created on the central part on each surface, approximately 1 mm apart. Micro-hardness values were determined by taking the average of three values for each surface. Vickers micro-hardness was calculated according to the following formula VH = 1854.4 P/d2, where VH is Vickers hardness in N/mm^2, P is the load in N, and d is the length of the diagonals in mm.DOC was calculated according to the following formula: DOC = (bottom Vickers hardness mean value/top Vickers hardness mean value) x 100.

Statistical analysis

The Number Cruncher Statistical System (NCSS) 2007 (Kaysville, Utah, USA) software was used for the statistical analysis. The conformity of the data to a normal distribution was evaluated with the Shapiro-Wilks test, and it was determined that the parameters were suitable for a normal distribution. The Student's t-test was used for pairwise comparison of quantitative data. Pearson's correlation analysis was used to evaluate the relationships between the variables. A value of $p < 0.05$ was used for all tests.

Results

Comparisons of the effect of polymerization of each composite with different light guide tips on DC and DOC are provided in Table 2. The DC of TEC reached over 55% of the clinically acceptable value, while TECBF and SF remained below this value. The DC of the TECBF and SF cured with a 13/8 mm diameter light guide tip was significantly higher than that of the groups cured with a 13/4 mm diameter tip ($p<0.01$). The DOC of TECBF and SF cured with a 13/8 mm diameter tip was significantly higher than that of the group cured with a 13/4 mm tip ($p<0.01$). Comparisons of the effect of polymerization of each composite with different light guide tips on the micro-hardness of the top and bottom surfaces are provided in Table 3. The bottom surface micro-hardness values for TECBF and SF cured with a 13/4 mm diameter light guide

***Table 2**. Comparison of the effects of light guide diameter of each composite on the degree of conversion (DC%) and depth of cure (DOC%) Different letters in the rows for each test indicate a statistically significant difference.*

Tests	**DC (%) (mean±SD*)**		***p***	**DOC (%) (mean±SD*)**		***P***
Light Guide Diameter	**8 mm**	**4 mm**		**8 mm**	**4 mm**	
TEC (control)	70.17±2.64^a	68.71±0.53^a	0.260	53.40±5.32^a	49.60±3.71^a	0.227
TECBF	34.15±2.50^a	29.62±1.61^b	0.009**	54.20±3.11^a	42.20±1.92^b	0.001**
SF	32.42±2.36^a	25.59±2.21^b	0.001**	54.00±3.67^a	25.00±5.43^b	0.001**

**SD: standard deviation. Student's t-Test **p<0.01.*

tip were significantly lower than those cured with a 13/8 mm diameter tip (p<0.01). There was no correlation between the DC of the composite resins evaluated in the study and the micro-hardness of the top surface, micro-hardness of the bottom surface, or DOC (Table 4).

determined a DC of 4 mm thick TECBF over 55% with 10 sec of light exposure. However, Tarle *et al.* (5) stated that the values measured from the bottom surfaces of the samples were significantly lower than those from the top surfaces and that for bulk-fill composites, 20 or 30 sec of light treatment provided better conversion of carbon-carbon double bonds to single bonds. Miletic *et al.* (3) stated that 10 sec is insufficient for adequate polymerization of high-viscosity bulk-fill composites and that at least 20 sec of light should be applied. In their study, Papadogiannis *et al.* (21) reported that DC was lower than 55% in all bulk-fill composites by applying light to bulk-fill composites, including TECBF, for 30 sec. In the literature, in studies where bulk-fill composites were cured for longer than the 10 sec recommended by the manufacturer, higher values were achieved with 20 sec (2,4,7,9,25-28) and 40 sec (29). The light curing units and light guide tip geometries used in these studies differed from those in this study. The difference between studies may have been due to the different light curing units, light guide tip geometry, and light exposure distance. While the light was applied through a 1-mm-thick microscope glass in our study, it was applied via direct contact with transparent tape in the other studies. Although light can be applied in laboratory studies with no distance between the composite and the light guide tip, this is not possible in clinical practice, and light can be applied at a distance of at least 1 mm from the composite in the mouth.

Table 3. *Comparison of the effects of light guide diameter of each composite on top and bottom surface micro-hardness [VH (top), VH (bottom)]. Different letters in the rows for each test indicate a statistically significant difference.*

Tests	**VH (top) (mean±SD*)**		***p***	**VH (bottom) (mean±SD*)**		***P***
Light Guide Diameter	**8 mm**	**4 mm**		**8 mm**	**4 mm**	
TEC (control)	60.82±2.15[a]	66.36±1.56[b]	0.002**	32.58±3.14[a]	32.84±2.24[a]	0.887
TECBF	72.71±2.99[a]	69.71±4.01[a]	0.217	39.39±1.69[a]	29.29±1.22[b]	0.001**
SF	72.93±1.04[a]	75.95±4.79[a]	0.205	39.34±2.37[a]	21.04±1.84[b]	0.001**

**SD: standard deviation. Student's t-Test **p<0.01*

Table 4. *Correlation between Vickers micro-hardness, depth of cure (%), and degree of conversion (%).*

Composite Group/ Light Guide Diameter		**Degree of conversion (%)**		
		Top surface micro-hardness	**Bottom surface micro-hardness**	**Depth of cure (%)**
TEC / 8 mm	r	0.441	0.217	0.037
	p	*0.457*	*0.726*	*0.953*
TEC / 4 mm	r	0.049	-0.001	-0.030
	p	*0.938*	*0.998*	*0.962*
TECBF / 8 mm	r	0.442	0.546	0.089
	p	*0.456*	*0.341*	*0.887*
TECBF / 4 mm	r	0.118	0.018	-0.100
	p	*0.850*	*0.978*	*0.873*
SF / 8 mm	r	-0.091	-0.628	-0.559
	p	*0.884*	*0.256*	*0.327*
SF / 4 mm	r	0.362	0.415	0.159
	p	*0.550*	*0.487*	*0.798*

r: Pearson correlation coefficient (p<0.05).

Discussion

In this study, the null hypothesis was rejected because the polymerization of bulk-fill composites with 13/8 mm or 13/4 mm diameter light guide tips caused a significant difference in DC and DOC.

The carbon-carbon double bonds within monomers are opened and converted into polymer chains with single bonds by activating polymerization in composite resins. The DC of Bis-GMA-based composites varies between 43–78% (19,20). Although there is no consensus regarding the DC required for composite resins to be used as restoration materials, it is expected to be at least 55% (21). In this study, the DC of the control group TEC conventional composites reached more than 55%, which is clinically acceptable, while the DC of TECBF and SF remained below this value. In this study, similarly to Salem *et al.* (22), the DC of TECBF, which was exposed to light for 10 sec, remained below 55%. Ilie *et al.* (23) determined the DC of TECBF, which was cured for 10, 20, and 40 sec, to be less than 55%. Tarle *et al.* (5) and Zorzin *et al.* (24)

Applying light from 1 mm or more causes a greater reduction in light intensity toward the bottom. This is even more important in bulk fill composites as bulk fill composites are applied thicker than conventional composites. Additionally, as recommended by the manufacturers, an additional 10 sec of light curing from the buccal and lingual surfaces of the tooth after matrix band removal may also contribute to a better restoration quality. However, in laboratory studies, light is applied only from the top surface. Insufficient polymerization of bulk-fill composites in vitro studies may be due to the lack of these additional light applications. However, some authors suggested that this additional light exposure may not be sufficient to ensure adequate polymerization due to the significant amount of light attenuation that occurs through the tooth structure (14,16)

Consistent with another study (17)**,** the DC of bulk-fill composites in this study was influenced by light guide tip diameter. The DC of TECBF and SF cured with a 13/4 mm diameter light guide tip were significantly lower than those cured with a 13/8 mm diameter tip. There was no significant difference between the samples in which the control group TEC was cured with 13/8 mm and 13/4 mm diameter tips. The light guide tips of the light-curing unit used in the study are turbo tips with a narrowing geometry toward the exit point of the light. The light beams, which narrow at the turbo tips, are scattered at the angle with which they exit the tip. The greater the ratio of the light guide tip's entry diameter/exit diameter, the greater the scattering of light (10,11). The beams of light that come out of the light curing unit used in this study with a diameter of 13 mm end as 8 mm in one light guide tip and 4 mm in the other. Since the 4 mm diameter tip has a higher narrowing rate, the light shows more scattering than the 8 mm diameter tip. TEC was applied with a layer thickness of 2 mm. Since the layer thickness is small, the light coming out of both tips of different diameters may not be scattered much, providing sufficient intensity of light energy for polymerization. TECBF and SF were applied in 4 mm and 5 mm thickness layers, respectively. The light was applied to the composites through a 1-mm-thick microscope glass. Given the thickness of the samples, the light must reach a depth of 5 mm for TECBF and 6 mm for SF. The reason why DC was lower when TECBF and SF were cured with a 13/4 mm diameter light guide tip may be because the light from the 13/4 mm diameter tip was scattered more than the 13/8 mm diameter tip, and not enough light reached the deep layers.

Comparing the curing of each composite with a 13/8 mm and 13/4 mm diameter light guide tip, the bottom surface Vickers hardness of TEC was no significant difference between the groups cured with 13/8 mm and 13/4 mm diameter tips. Since the conventional composite TEC was applied with a thickness of 2 mm, the light energy reached the lower surface sufficiently, and adequate polymerization may have been achieved with both tips. However, the bottom micro-hardness of the groups of TECBF and SF cured with a 13/4 mm diameter tip was significantly lower than those with a 13/8 mm diameter tip. In this case, the scattering of the light applied from the 13/4 mm diameter tip, as opposed to the 13/8 mm tip, in composites of 4 mm (TECBF) and 5 mm (SF) thickness may have caused insufficient polymerization of the bottom surface. Studies conducted with different light-curing units have reported that the micro-hardness values on the bottom surface of bulk-fill composites polymerized with wide-diameter tips are higher than those polymerized with narrow-diameter tips (13,30).

This study determined DOC by dividing the bottom Vickers hardness value by the top surface value. The fact that the composite resins' bottom and top surface hardness are equal indicates the ideal polymerization rate. Generally, polymerization of the top surface of composite resins occurs successfully. In contrast, polymerization of the bottom surfaces remains lower due to reduced light energy when it scatters or is absorbed as it passes through the composite. The bottom/top surface micro-hardness ratio is ideally desired to be 100%, but 80% indicates that an acceptable DOC has been achieved (31). In this study, all the composite resins cured for 10 sec with 13/8 and 13/4 mm light guide tips remained below 80%. Despite some studies showing that high-viscosity bulk-fill composites provide an 80% bottom/top surface hardness ratio by curing for 10 sec (32,33), many studies have found that 10 sec of light application is insufficient for high-viscosity bulk-fill composites. (3,5,24,34-36). In different studies, a DOC of over 80% was reached by applying light for 20 sec (3,34,35,37), 30 sec (5,24,38), and 40 sec (39). However, in some studies, TECB could not provide sufficient DOC at 4 mm, SF, and SonicFill3 at 4 and 5 mm with 20 seconds of light application (40,41). Garoushi *et al.* (1) didn't reach sufficient DOC in TECBF composite with 40 sec light application. Rocha *et al.* (42) also stated that the depth of TECBF remained below 80% when applying light for 21 and 9 seconds in different light-curing modes, corresponding to 20 J/cm^2 of radiant exposure. In the mentioned studies, the experimental conditions were different, and the properties of the light curing units used in polymerization also varied. The recommendations from manufacturers of composite resins regarding polymerization are usually related to the wavelength, light intensity, and duration of light. However, the diameter and geometry of the light guide tips of the light-curing units also affect polymerization (43). In one study, bulk-fill composites cured for 20 sec with a 10 mm diameter parallel light guide tip exceeded an 80% bottom/top surface ratio. However, despite the higher light intensity, the composites cured for the same duration with a 13/8 mm turbo-tipped light-curing unit remained below this rate (43). In our study, the DOC of TEC cured with a 13/4 mm diameter tip was not different from the samples cured with a 13/8 mm diameter tip. However, the DOCs of TECBF and SF cured with a 13/4 mm tip were lower than those cured with a 13/8 mm optical tip. The greater scattering of the light transmitted from the 13/4 mm diameter tip than the light emitted from the 13/8 mm tip may have caused insufficient light to reach the bottom of the composite. In addition, the light intensity decreases toward the periphery of the tip. Vickers hardness values can vary between areas exposed to high-intensity light and low-intensity light (15,44). In this study, the molds in which the composites were placed were 4 mm in diameter. Both optical tips, 13/8 mm and 13/4 mm in diameter, were in turbo geometry. Especially for the 13/4 mm diameter optical tip that exactly matches the diameter of the molds, the light intensity may have decreased in the edge areas of the samples during light application. For this reason, the polymerization of the bottom surfaces of the samples with thicknesses of 4 mm and 5 mm may have been

adversely affected.

In our study, although the DC of TEC was above 55%, the DOC below 80% may not have been caused by insufficient polymerization but by the polish applied to the top surfaces of the samples. Polishing increases the surface hardness of the bulk-fill composites (31). In this study, because the bottom surfaces of the samples were not polished, the micro-hardness increased because the polish did not occur on the bottom surfaces. In fact, in the micro-hardness measurements of TEC without polishing, the micro-hardness values of the bottom surface were close to ours, but the top surface measurements were lower than we obtained (34,45). In this study, it is thought that polishing the top surface of the samples caused the top surface Vickers hardness values to increase, resulting in relatively low rates when the bottom/top surface ratio was made.

In this study, no correlation was found between the DC of the composites and their micro-hardness. Other studies have shown no correlation (7,9,12,29) or lack of correlation (1) between DC and the micro-hardness of TECBF, FU, SF, and bulk-fill composites of different viscosities. The DC and surface hardness of composite resins are related to each other. However, the DC of the material and its physical properties do not change at the same rate. DC alone does not provide information about the characterization of the polymer network structure of the composite resin, and a high DC does not always result in better properties, such as the surface hardness of the material. Direct methods, such as FTIR analysis, provide information about the amount of conversion of double bonds to single bonds in the resin but not the polymer network structure of these bonds. The crosslink density of composite resins with similar DCs may differ. High molecular weight monomers like Bis-GMA have a lower conversion rate than low molecular weight monomers. However, the monomers they form are more intense crosslinks when compared with those formed by low-weight monomers. The polymer chains formed during polymerization can form linear, branched, or cross-links. The high crosslink density in the polymer structure causes an increase in the properties of the material, such as surface hardness (5,7,46). The structure of the monomers in the organic matrix of the composites in this study was different, as were the ratios, types, and shapes of inorganic particles. The lack of a correlation between DC and the micro-hardness of the composites in this study is thought to be due to these differences.

This study was conducted under in vitro conditions, and one of the limitations was that the samples were cured only on their top surfaces. Manufacturers recommend an additional 10 sec cure on both the buccal and lingual surfaces of the tooth in posterior restoration. Therefore, the results may not fully reflect clinical practice. Another limitation of the study was the different thicknesses of the materials. In this study, sample thickness was 2 mm for TEC, 4 mm for TECBF, and 5 mm for SF, adhering to the maximum DOC recommended by the manufacturer. 2 mm thickness for the bulk fill composites could have been added to the experimental groups. However, the study aimed to evaluate whether the maximum layer thickness recommended by the manufacturers was safe for clinical use. For this reason, the layer thickness of the materials was applied at the maximum thickness recommended by the manufacturer. In addition, SonicFill 2 was used in this study. Currently, SonicFill 3 is in clinical practice. Due to differences between the contents of the two materials, the results of this study may not reflect the features of SonicFill 3.

Conclusion

Within the limitations of the current study, it was concluded that The DC and DOC of bulk-fill composites cured with a 13/8 mm diameter light guide tip were higher than those cured with a 13/4 mm light guide tip. The DC of light-cured bulk-fill composites applied at the layer thickness recommended by the manufacturer remained below the clinically acceptable level of 55%, and DOC was below 80%.

Türkçe öz: *Bulk-fıll kompozitlerin farklı çaplardaki optik uçlarla polimerize edilmesinin monomer dönüşüm derecesi ve polimerizasyon derinliği üzerine etkisi. Amaç: Bu çalışmanın amacı optik uç çapının bulk-fill kompozitlerin monomer dönüşüm derecesi, mikrosertlik ve polimerizasyon derecesi üzerine etkisinin geleneksel bir kompozitle karşılaştırmalı olarak incelenmesidir. Gereç ve Yöntem: 60 örnek (n=5) 4 mm çapında kalıplara Tetric EvoCeram 2 mm, Tetric EvoCeram Bulk Fill 4 mm, SonicFill2 5 mm kalınlığında yerleştirilmiş ve 13/8 veya 13/4 mm çapında turbo optik uçlu LED ışık kaynağıyla 10 mm polimerize edilmiştir. 37°C'de karanlık ve kuru ortamda 24 saat bekletilen örneklerden 30 adedinin üst yüzeyleri cilalanmış, üst ve alt yüzeylerinden Vickers mikrosertlik cihazı ile mikro-sertlik ölçümleri yapılmıştır. Toz haline getirilen diğer 30 örneğin FTIR-ATR cihazı ile monomer dönüşüm dereceleri ölçülmüştür. Polimerizasyon derinliği alt yüzey mikro-sertlik değerinin üst yüzey değerine oranlanması ile belirlenmiştir. Elde edilen verilerin analizi Shapiro-Wilks test, Student's t-test, and Pearson's korelasyon analizi ile yapılmıştır ($p < 0.05$). Bulgular: 13/8 mm çapında optik uçla polimerize edilen bulk-fill kompozitlerin monomer dönüşüm derecesi ve polimerizasyon derinliği 13/4 mm ile polimerize edilenlerden daha yüksektir ($p<0.01$). Üreticinin önerdiği tabaka kalınlığında uygulanan bulk-fill kompozitlerin monomer dönüşüm derecesi klinik olarak kabul edilebilir değer olan %55'in altında, polimerizasyon derinliği %80'in altında kalmıştır. Sonuç: Bulk-fill kompozitlerin farklı çaptaki optik uçlarla polimerize edilmesi monomer dönüşüm derecesi ve polimerizasyon derinliğini etkilemektedir. Anahtar Kelimeler: Bulk-fill kompozit, monomer dönüşüm derecesi, polimerizasyon derinliği, optik uç çapı, mikro-sertlik.*

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