



ORIGINAL ARTICLE

The Effect of Different Light Curing Units and Tip Distances on Translucency Parameters of Bulk fill Materials

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Received 26 June 2021; revised 31 March 2022; accepted 6 April 2022

Available online 12 April 2022

KEYWORDS

Bulkfill composite;
Light curing units;
Translucency parameter;
Composite Resin

Abstract Objectives: To evaluate the effect of light curing unit (LCU) types and distance from light curing unit tip on the translucency parameters (TP) of bulk fill composite materials.

Materials and Methods: Two bulk-fill resin composites and one nanohybrid composite were used in this study. The specimens were divided into groups based on the type of curing unit used, and further subdivided based on the distance of the curing source to the surface of the resin composite. Translucency was evaluated at 4 mm thickness (for the bulk-fill) and 2 mm thickness (for nanohybrid) after curing using two different light curing units at zero, 2 mm, and 4 mm distance. The results were analyzed using two-way ANOVA at the significance level of a p-value of < 0.05.

Results: Among all the tested materials, Filtek Bulk Fill Posterior RBC showed the highest TP at 0 mm distance when cured with Blue phase G2 LED LCU and it was the least affected by the differences in distances. However, Filtek Z350 nanohybrid composite had no significant differences between the three distances when cured with Blue phase G2 LCU.

Conclusion: Translucency values among the studied bulk-fill materials are affected by material composition, curing units and the distance of the tip of the light source to the restoration surface.

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Peer review under responsibility of King Saud University.



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1. Introduction

With the advances in dental materials, instruments, and clinical techniques, composites have become the most commonly used direct restorative material to satisfy patients demands for esthetic restorative treatment. (Kwon, 2012).

One of the major problems of resin-based composites (RBCs) is polymerization shrinkage. Polymerization shrinkage

generates stress at the tooth restoration interface, resulting in debonding when the shrinkage stress exceeds the bond strength (Ferracane 2005).

In order to minimize the stress from polymerization shrinkage and to acquire adequate mechanical properties of composite, an incremental placement technique is advised, in which the composite is layered and cured in increments of 2 mm. (Bicalho et al. 2014) However, this technique is time consuming (Bucuta and Ilie 2014) and if not performed properly can result in void incorporation within the bulk and at the margins of the restoration, which may lead to weakening the restoration or microleakage. (Opdam et al. 1996).

Recently, bulk-fill composites have been developed to simplify the composite resin placement technique. Manufacturers claim that, compared to conventional composites, bulk-fill composites create a lower polymerization shrinkage stress and have higher light transmission properties due to reduction of light scattering at the filler matrix interface by either increasing the filler scope or decreasing the filler quantity. Thus, bulk-fill composites can be used for increments of up to 4–5 mm thickness. (Bucuta and Ilie 2014).

Light-curing units (LCU) play an important role in the development of the basic properties of RBCs. Quartz-tungsten-halogen (QTH) units has been widely used for polymerizing resin-based dental materials for decades. (Martin, 1998; Mills et al. 1999; Kusgoz et al. 2011) However, they have largely been replaced by light-emitting diode units (LED). Most of the currently used LED LCUs belong to the second-generation with a single, high powered diode. Improving the diode technology allowed a continuous increase in the unit's irradiance and, accordingly, a decline in the recommended irradiation time. (Rencz et al. 2012).

The narrow spectrum of monowave LED LCUs may block their ability to optimally cure bulk-fill composites that include multiple photoinitiators with varying peak absorption ranges; however, polywave curing LED LCUs (third generation) were introduced and are able to radiate different wavelengths of light to polymerize different photoinitiators. (Menees et al. 2015).

Studies demonstrated that polymerization time of 10 or 20 s with modern LED LCUs are sufficient for complete curing of RBCs. (Soh and Yap 2004) These findings encouraged the manufacturers of LED LCUs to claim that a further increase in irradiance will allow even shorter polymerization times, for a clinically acceptable polymerization. (Yap and Seneviratne 2001).

The distance between the light source and composite resin directly affects the light intensity on the resin surface, as the light intensity diminishes when the distance from the tip to the resin composite is increased. Thus, the most common clinical recommendation for the position of the light curing appliance tip is up to 1 mm from the resin restoration surface. (Pires et al. 1993).

During the curing process, the light that passes through the RBC is absorbed and scattered based on the particle size of fillers and refractive indices of resin matrix and fillers. Consequently, the light intensity is decreased and its effectiveness is reduced as the depth increase. (Watts DC, 1984) The reason for the enhanced depth of cure of these bulk fill RBCs is considered to be its increased translu-

ency, due to larger filler size and less filler load (dos Santos et al. 2008); the composition and the initiator systems are comparable to the conventional RBCs. (Garoushi et al. 2016).

Translucency is the relative amount of light transmitted through the material. (Brodbeck et al. 1981) and is usually measured with the translucency parameter (TP). The TP is defined as the color difference (ΔE) between a uniform thickness of a material over a white and a black background. (Johnston et al. 1995).

Esthetic restorations should reproduce the translucency of natural teeth. Translucency and opacity have been viewed as vital properties of composite resins since they are an indication of the quality and quantity of light reflection. The main component of composite resins that significantly affects the translucency is the inorganic filler. Many studies have focused on the influence of the filler on translucency of dental composites in terms of filler type, particle size and content. (Liu et al. 2010; de Oliveira et al. 2016).

Azzopardi et al., investigated the effect of the resin matrix composition on the translucency of experimental dental composite resins. Three types of unfilled resin matrices (TEGDMA-, UDMA- and BisGMA-based) were formulated and light cured. Different experimental dental composite resins with constant filler loading but varying in the type of monomer and the content of BisGMA were fabricated. Results have shown that the amount of BisGMA used in the resin matrix has a significant effect on the translucency of silica filler-containing dental composite resins. (Azzopardi et al. 2009).

Son and colleagues investigated the translucency parameter of bulk-fill composites which have different light attenuation properties and filler contents. Five Bulk-fill [Filtek Bulk Fill (FB), SureFil SDR (SS), Venus Bulk Fill (VB), SonicFill (SF), and Tetric N-Ceram Bulk Fill (TB)] and two resin-based composites [Tetric N-Ceram (TN) and Filtek Z350XT Flowable (ZF)] were chosen. Bulk-fill had significantly higher translucency values than conventional RBCs TN and ZF. (Son et al. 2017).

A linear correlation between BisGMA percentage in the resin matrix and light transmission of composite resins indicates that the addition of BisGMA has a direct effect on translucency even when the filler content is constant. It can be assumed that the addition of BisGMA to TEGDMA will increase the refractive index of the resin system, thereby potentially enhancing its optical match with the silica filler system.

To the authors' knowledge no studies have examined the interaction between the light curing unit types and the distance from the light curing unit tip on translucency of the new bulk-fill materials. Therefore, the aim of this study was to evaluate the effect of light curing unit types and the distance from light curing unit tip on translucency of different bulk fill composites materials.

The null hypotheses:

- 1- There is no difference in using different distances from the light curing unit tips on TP.
- 2- There is no difference in TP of different composite resin materials.
- 3- Translucency of bulk fill composite is not significantly affected by using different light curing units.

2. Materials and methods

The present research study was approved by the Institutional Review Board of College of Dentistry, King Saud University, Saudi Arabia (CDRC Project No. PR 0062).

Sixty specimens each of two bulk-fill resin composites, and 30 specimens of one nanohybrid resin composite were used in this study as shown in Table 1.

Two different light curing tips were employed for this study which are shown in Table 2. The light curing tip was positioned at zero, 2 mm, and 4 mm distance from the surface of the composite material. Curing time was 20 s for the two light curing units.

2.1. Sample size determination

Estimated standard deviation for translucency test was 1.7 at $\alpha = 0.05$ with marginal error of 95 confidence intervals is equal to 0.86 and sample size should be at least 10 in each group. (Ajaj et al. 2015).

2.2. Specimen preparation

For the fabrication of the specimens a customized sectional Teflon mold (10 mm in diameter and 4 mm depth) was employed which had a marking at a 2 mm depth. Bulk-fill composite resin was packed to full thickness which the conventional composite was filled till the 2 mm marking. Bulk-fill specimens were divided according to the material brand into two groups ($n = 60$) then subdivided according to the light curing unit type ($n = 30$) and tip distances into 3 groups for each bulk-fill composite material ($n = 10$). For the conventional composite (control group), 30 specimens were fabricated and divided into two groups ($n = 15$) according to the light curing unit type, then subdivided according to the distances from the light curing unit tip into three groups ($n = 5$). Curing time was standardized at 20 s, with light curing tip distances of zero, 2, and 4 mm for each group. The distance from the composite surface was calibrated and stabilized using a laboratory

ring and clamp stand (Dentalfarm, Torino, Italy). Analysis and measurement of the irradiance values, spectrum energy, and total energy delivered for each specimen was performed using a MARC- RC device (blueLight Analytics Inc., Halifax, NS, Canada) (Fig. 1).

2.3. Translucency parameter measurement (TP)

The TP was measured using a spectrophotometer (Color Eye 7000 A, Model C6, Gretag Macbeth, New Windsor, NY, USA) according to the CIELAB color scale relative to the standard illuminant D65 against a white background ($L^* = 93.26$, $a^* = -0.61$, and $b^* = 2.09$) and a black background ($L^* = 2.93$, $a^* = 0.38$, and $b^* = -0.34$). Before measuring each group, the spectrophotometer was calibrated with standard calibrating blocks (white and black) according to the manufacturer's recommendation. Three readings were made for each sample.

2.4. Calculation of translucency parameter (TP)

The translucency parameter values were determined by calculating the color difference between readings over the black and white background for the same specimen, using the following formula:

$$TP = \{(L^*_B - L^*_W)^2 + (a^*_B - a^*_W)^2 + (b^*_B - b^*_W)^2\}^{\Delta 12}$$

Subscripts 'B' and 'W' refer to the color coordinates over a black and white background, respectively.

2.5. Statistical analysis

Data were statistically analyzed using IBM® SPSS® Statistics Version 22 for Windows (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA). Normality was tested by the Shapiro-Wilk test and homogeneity of variance was analyzed by Levene's test. Data were presented as mean and standard deviation (SD) values. Due to the detected variance

Table 1 Resin based composites materials used in this study according to manufacturer's data.

Materials/ shade	LOT number	Materials type	Resin matrix	Filler
Tetric N-Ceram Bulk Fill* (Ivoclar-Vivadent, Lichtenstein) Shade IVA	LOT T47219	packable hybrid bulk-fill composite	Bisphenol A Glycidyl Methacrylate (Bis GMA), bis[4-(2-ethoxy-3-methacryloyloxy propoxy) phenyl propane (Bis-EMA) and urethane-dimethacrylate (UDMA).	Fillers content consist of a barium glass, 17 % prepolymer, ytterbium trifluoride and mixed oxide. Filler loading 75–77% by wt, 53–55% by volume, inorganic fillers particle size is between 0.04 and 3 μm , mean particle size is 0.6 μm
Filtek Bulk Fill Posterior restorative (3 M ESPE, USA) Shade A2	LOT N682081	packable nanofilled bulk-fill composite	ERGP-DMA, diurethane- DMA, and 1, 12-dodecane- DMA	Non-agglomerated/non-aggregated 20 nm silica filler and 4–11 nm zirconia filler, aggregated zirconia/silica cluster filler, and ytterbium trifluoride filler agglomerate 100 nm particles. Filler loading 76.5% by wt, 58.4 by volume.
Filtek Z350 XT** (3 M ESPE, USA) A2 body shade	LOT N6 77,462	Nonofilled	Bis-GMA, UDMA, TEGDMA (Tetraethyleneglycol Dimethacrylate), PEGDMA (Poly ethylene glycol) diacrylate), Bis-EMA	Non-agglomerated/non-aggregated 5–20 nm silica filler and 4–11 nm zirconia filler, and aggregated zirconia/silica cluster filler. Mean size: 0–6 to 1.4 μm (78.5%).

*The European trade name Tetric Evo Ceram Bulk fill.

**Trade name in North America Filtek supreme ultra.

LED LCU	Company	Serial No.	Type	Light irradiance (mW/cm ²)	Light probe diameter
Blue phase G2	Ivoclar Vivadent	222,788	Polywave LED with broad spectrum wavelength (385 to 515 nm)	1200 mW/cm ²	10 nm
Elipar Deep cure- S	3 M ESPE	932,125	Single wave LED (430–480 nm)	1470 mW/cm ²	10 nm

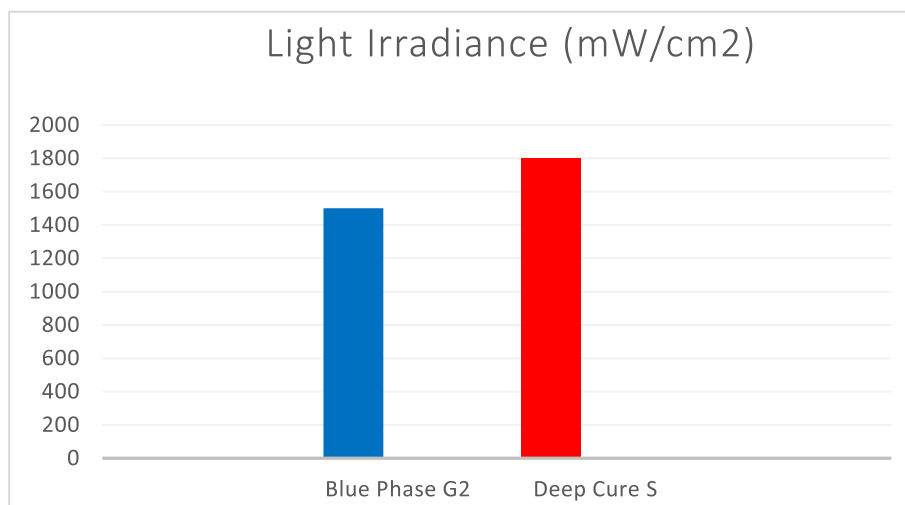


Fig. 1 The spectrum emission for the Blue Phase G2 LCU at 20 s (blue line) and Deep Cure S (red line).

heterogeneity between different groups of composites, two-way analysis of variance (ANOVA) followed by one-way ANOVA was used. Results were analyzed at the significance level of a p-value of < 0.05 .

3. Results:

The mean TP values of the resin composites with different light curing units and distance from light curing unit tips are shown in Table 3 and Fig. 2. Among the resin composites, the Filtek Bulk Fill composite (Blue phase G2 light curing unit at 0 mm distance from light curing unit tip) had the highest TP (13.92 ± 1.04) and Filtek Z350 composite (Deep Cure S light curing unit at 0 mm distance from light curing unit tips) had the lowest TP (4.78 ± 1.09).

The results of the bulk-fill materials showed statistically significant difference in the translucency parameter. Filtek Bulk Fill posterior composite cured with blue phase G2 LCU at 0 mm distance showed significantly higher translucency than 2 and 4 mm when compared with Tetric N Ceram bulk fill and Filtek Z350 nanohybrid composite. However, Tetric N Ceram cured with Deep Cure S LCU showed significantly higher translucency at 2 mm distance than 0 and 4 mm. Tetric N Ceram bulk fill composite cured with blue phase G2 LCU showed significantly lower translucency at 4 mm distance than 0 and 2 mm. Filtek Z350 nanohybrid composite had no significant differences between the three distances when cured with blue phase G2 LCU. However, it showed significantly higher translucency at 0 mm distance than 2 and 4 mm when cured with Deep Cure S LCU.

4. Discussion

Bulk fill composites are the latest trend in restorative materials, which can be placed in one large increment. Bulk fill composite materials, have greater translucency properties due to the reduced filler content and increased filler size. To place clinically successful restorations, it is important to achieve proper polymerization through the entire thickness of resin based composite materials. (Abed et al. 2015) The Light curing system and the distance between the composite surface and the tip of the light source are crucial considerations for the success of the final restoration. (Maghaireh et al. 2013).

The results of this study confirmed that the distance between the light tip and the resin composite can affect the light intensity that reaches the restorative material. Thus, the first null hypothesis was rejected.

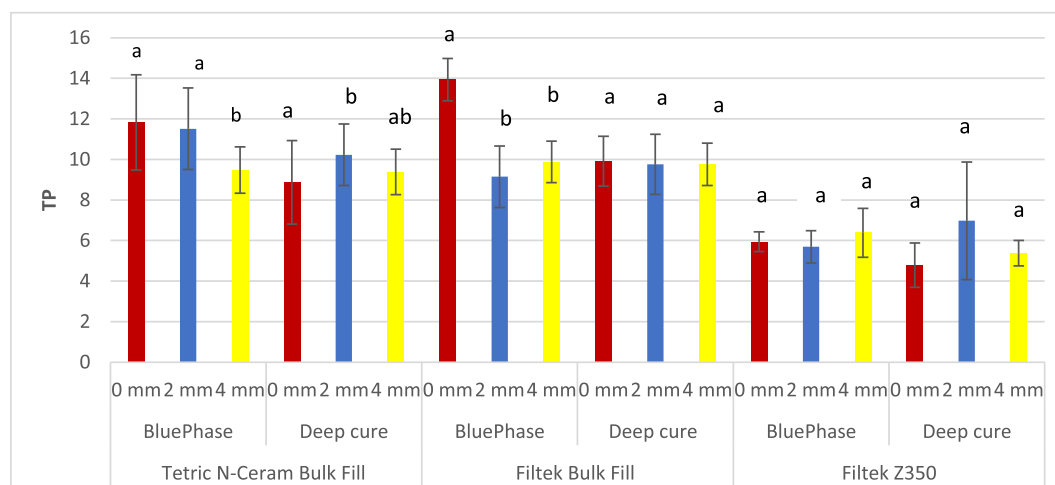
Durner *et al.*, found that significantly lower irradiance may be reaching the surface of the resin in the tooth that is 2 to 8 mm away from the light tip. (Durner et al. 2012) It is possible that different areas of the resin received different amount of light due to scatter and light attenuation leading to this increased variability. (García-Contreras et al., 2015).

Translucency parameter varies with different distances from the material surface with general trend towards high TP at 0 mm distance from the surface for Blue Phase G2 LED LCU. Furthermore, Tetric N Ceram bulk fill and Filtek Z350 nanohybrid RBCs cured with Deep Cure S showed higher TP at 2 mm distances. However, Filtek Bulk Fill Posterior RBC was not affected by the distance from the surface with this light cure unit. This may be attributed to changes

Table 3 Result of Two-Way ANOVA showing mean (\pm SD) of translucency parameter and significant differences between the three distances for each material and LCU combination.

Material	Curing type	Light tip distance	Mean	Standard Deviation	Df	Mean Square	F	Sig
Tetric N-Ceram Bulk Fill	Blue phase G2	0 mm	11.82 ^a	2.35	2	48.49	13.39	0.000
		2 mm	11.51 ^a	2.00				
		4 mm	9.48 ^b	1.14				
	Deep Cure S	0 mm	8.86 ^a	2.06	2	14.13	5.43	0.006
		2 mm	10.22 ^b	1.51				
		4 mm	9.38 ^{ab}	1.12				
Filtek Bulk Fill	Blue phase G2	0 mm	13.92 ^a	1.04	2	199.26	134.80	0.000
		2 mm	9.14 ^b	1.51				
		4 mm	9.87 ^b	1.02				
	Deep Cure S	0 mm	9.91 ^a	1.22	2	0.237	0.148	0.862
		2 mm	9.75 ^a	1.48				
		4 mm	9.75 ^a	1.04				
Filtek Z350	Blue phase G2	0 mm	5.93 ^a	0.486	2	1.85	2.39	0.104
		2 mm	5.68 ^a	0.797				
		4 mm	6.38 ^a	1.20				
	Deep Cure S	0 mm	4.78 ^a	1.09	2	19.24	5.76	0.006
		2 mm	6.97 ^b	2.90				
		4 mm	5.37 ^{ab}	0.631				

*Small case superscripts letter shows Scheffe Post Hoc comparisons within distances for each material and light curing unit.

**Fig. 2** Bar chart of mean (\pm SD) of translucency parameter values.

in TP after light curing and is most likely material dependent. These findings agree with a study by Sidhu and others, who evaluated color and translucency changes caused by light curing resin composite materials. Their results revealed that translucency changes during light curing of Charisma lead to a statistically significant increase in TP. However, no difference was observed in the other resin composite materials. (Sidhu et al. 2006) It is also probable that this difference is related to the particle size of the three materials. Like Tetric N Ceram Bulk Fill, Filtek Z350 has filler particles of nano silica and zirconia/silica nano clusters with a size range of 5–20 nm. Larger particles can deflect and scatter light waves and might interfere with the light reaching the bottom of the restorations. (García-Contreras et al., 2015). The second null hypothesis stating that there is

no difference in TP of different composite resin materials was also rejected.

The results of this study showed that TP decreased with increasing light tip distances. Filtek bulk fill posterior at 0 mm distance had the highest TP compared to Tetric N Ceram and Filtek Z350 when cured with Blue Phase G2 LED LCU. On the other hand, Filtek Z350 nanohybrid RBC at 0 mm distance had the lowest TP when cured with Deep Cure S LED LCU. These findings concur with a study by del Mar Pérez and colleagues, who found that there is a significant influence of the type of light curing units on the changes in TP of resin based composite materials. (del Mar et al., 2009) Therefore, the third null hypothesis was rejected.

The main component of resin-based composites are the inorganic fillers and the organic matrix that contain various

types of monomers. Differences in monomers, filler type and size, and refractive index mismatch between the organic matrix and inorganic filler particles might have a significant influence on the translucency and light transmission of RBC materials. (Mikhail *et al.* 2013) Faria *et al.*, evaluated the effect of the composite shade and distance from the light curing unit tip on the irradiance reaching the bottom of composites and on the depth of polymerization. They reported that both composite shade and distance from LCU tip might affect the light transmission and depth of polymerization. (Faria *et al.* 2017) The present study is in agreement with these findings.

Clinicians should exercise caution when restoring deep cavities when selecting and placing resin based bulk filling materials. In Filtek Bulk Fill Posterior, the significantly higher TP than the others may allow more light to penetrate deeper up to 4 mm, which could result in better polymerization efficiency. However, with Tetric N Ceram Bulk Fill these properties might not be optimal and can affect the composite resin restorations longevity and function.

5. Conclusion

- The distance between the tip of the light source and the restoration surface is an essential factor to consider because it significantly affects translucency of the resin based composite materials.
- High translucency parameter of composite resin increases the light transmission into the entire resin thickness and could affect the efficiency of polymerization.
- Different light curing units can affect the TP of bulk-fill composite materials.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors would like to thank the College of Dentistry Research Center and Deanship of Scientific Research at King Saud University, Saudi Arabia for their technical support and for approving and funding this research. We also thank Prof. Maan AlSha'afi for his valuable contribution to this work, as well as the College of Dentistry physical laboratory staff for their cooperation and support.

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