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Comparison of the depth of cure of flowable composites polymerized at variable increment thicknesses and voltages: An In vitro study

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Original Article

Comparison of the Depth of Cure of Flowable Composites Polymerized at Variable Increment Thicknesses and Voltages: An *In vitro* Study

Abstract

Objectives: The aim of this study is to compare the depth of cure of two composite materials (SDR and Filtek bulk-fill) cured at variable increment depths (2, 4, and 6 mm) and voltages (180 and 220 volts). **Materials and Methods:** Each sample of the composite material was packed in a mold of 2 mm, 4 mm, and 6 mm and curing light (quartz tungsten halogen) of optimal intensity was exposed for 20 s at 2 different voltages on each specimen. After curing, the specimens were removed and the composite on the nonexposed end was scraped with a plastic instrument. The remaining composite thickness was measured using a digital Vernier caliper. The reading was divided by half to follow the ISO 4049 method. Independent sample *t*-test, one-way ANOVA, and linear regression analysis were applied. Level of significance was kept at 0.01. **Results:** The mean DOC of SDR and Filtek were 1.93 ± 0.82 and 1.77 ± 0.65 mm. Lowering the voltage from 220 to 180 volts reduced the depth of Filtek from 1.87 ± 0.74 to 1.67 ± 0.54 mm, whereas the DOC of SDR remained unchanged at 1.93 mm at the two voltages. The adjusted R^2 for the depth of cure was 0.93 when the increment thickness, voltage, and restorative material were taken together in the regression model. **Conclusions:** There was no statistically significant difference between SDR and Filtek for the depth of cure at 2 and 4 mm increments. However, at 6 mm increment, the SDR cured significantly deeper than the Filtek. Around 91% variation in the depth of cure of these composites materials is explained by increment thickness alone.

Keywords: *Dental composite restoratives, depth of cure, polymerization*

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Introduction

Depth of cure of resin composites is essential for the clinical success of these materials. It has been observed that if the composite is inadequately polymerized, it results in poor development of its physical properties.[1] During polymerization of a composite restoration, shrinkage of the restorative material can occur as freely moving monomers get converted to highly cross-linked polymers. This polymerization shrinkage creates contraction stresses at tooth-restoration interface. The resultant volumetric contraction gives rise to unrelieved stresses and can eventually lead to sensitivity, marginal staining, and secondary caries.[2,3] All these can have catastrophic results on the longevity of the restoration. Factors such as matrix phase of the composite material,[4] amount of fillers loaded,[5] polymerization rate,[6] and the C factor of the cavity influence the magnitude of the polymerization contraction.

Light curing the posterior composite resin restorations is associated with the decrease in curing-light intensity with the depth of the material. It has been proven that the intensity of light at a given depth and for a given irradiance period is critical in monomer conversion, and is significantly associated with mechanical properties, biocompatibility, color stability of the material and thus, the longevity of the restoration.[7]

Many options have been proposed to overcome or minimize the shrinkage stresses that develop during polymerization. It has been recommended that composite resins should be placed in increments of 2-mm thickness and should be in contact with no more than two walls of the cavity preparation, to reduce the C-factor. However, it has been observed that polymerization shrinkage stresses still develop regardless of the technique employed and remains a significant factor in the failure of these types of restorations.[8] Applying a low-elastic modulus liner as the

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first increment between the tooth structure and the resin composite has also shown to minimize the internal stresses which develop while curing.[9] Other methods include selecting a particular type of curing light to decrease the shrinkage. Quartz tungsten halogen (QTH) light units have been widely used in dental offices, although newer LED type curing units are now more commonly available. To adequately cure a 2 mm increment of resin composite, a QTH light unit must deliver a minimum power intensity of 300–400 mW/cm^2 in a 40 s cure.[10] However, if the restoration does not receive sufficient energy at the correct wavelength, the degree of conversion will remain inadequate; resulting in a weak restoration with poor mechanical properties.[11]

In the last few years, there has been a trend toward developing resin restorations which can save time during the placement step. The composition of these new materials has been altered in different ways to allow for the increased depth of curing while retaining the low shrinkage values.[12] Bulk-fill composites are one of the examples of these types of restorations. These have been developed with a promise of greater depth of cure because their clinical recommendations suggest that they can be placed in a 4-mm bulk increment.[13] An important limitation with conventional resin-based restorations was an increased treatment time due to the placement of restorative in increments and chances of incorporation of air or moisture contamination between increments. Bulk-fill flowable composites are supposed to save time and reduce the chances of air entrapment by allowing bulk cure. However, the flowable composite needs to be subsequently covered by a conventional composite on the occlusal aspect. Nevertheless, an ideal bulk-fill material would be one that could be placed into a cavity preparation with a high C-factor but would still exhibit very little polymerization shrinkage stress while maintaining a high degree of cure throughout the bulk of the restoration.

The first of these kind of composites introduced was SDR (Dentsply, USA), a posterior bulk-fill flowable base material which can be cured up to a depth of 4 mm. It has a photoactive group in a modified urethane dimethacrylate resin having 60%–70% less shrinkage when compared to other conventional methacrylate-based resins.[14] SDR is available in one universal shade, and it has to be overlaid with a posterior composite for replacing missing occlusal/facial enamel after the initial increment. SDR is also said to have a self-leveling feature that allows it to intimately adapt to the prepared cavity walls, whereas Filtek bulk-fill (3M-ESPE, USA) lacks this feature.[15] Literature suggests that polymerization stresses for SDR composites are considerably lower than that of other flowable materials.[16] Filtek bulk-fill is available in four different shades, i.e., A1, A2, A3, and universal with filler loading of 42% by volume.[17]

Bulk-fill flowable composites are generally recommended for use as base/liner underclass I and II restorations. They can also be used exclusively for Class III and V restorations. Mostly, they are used as core build-up materials when at least half of the coronal tooth structure is remaining to provide structural support to the tooth for the crown preparation. At present, there is a growing trend toward the use of bulk-fill materials among clinicians due to simplified protocol. However, because of the lower mechanical properties of most bulk-fill composites, their use as primary restorations under high occlusal load is controversial.[18]

In addition to the intensity and voltage of the curing units,[19] the exposure time and wavelength of the light determine the depth of cure. The type of photoinitiator incorporated in the composite material,[20] the shade of the resin,[21] the size of filler particles as well as the amount of filler present, the thickness of the restorative increment, the viscosity of the composite[22] are also important.

The objective of this study was to compare the mean depth of cure of two composite materials (SDR and Filtek bulk-fill) cured at incremental depth of 2, 4, and 6 mm as determined by the ISO 4049 method at 2 different voltages, i.e., 180 and 220 volts.

The null hypothesis was that there would be no significant difference in the mean depth of cure of the two materials, i.e., SDR and Filtek bulk-fill.

Materials and Methods

Since it was an *in vitro* study done on composites, Ethics Review Committee exemption was sought. No ethical considerations were present in this *in vitro* study. The study was conducted in Dec 2016 at the dental clinics in Aga Khan Hospital, Karachi, Pakistan.

The sampling technique was simple random. Inclusion criteria were SDR (Dentsply, USA) and Filtek bulk-fill (3M, ESPE, USA) flowable composite materials. Whereas any damaged, improperly cured or expired material was excluded from the study. The sample size was calculated using a statistical calculator "Sample Size Determination in Health Studies, WHO." Reference for sample size calculation was taken from the study of Garoushi *et al*.[17] who reported that the mean depth of cure of cure of SDR to be 4.30 mm (±0.30) and for Filtek bulk-fill to be 4.7 mm (±0.15). Keeping this difference at the level of significance of 0.01 and power of study at 0.99, our sample size per group turned out to be 28, which was inflated to 42 composites per group.

Each sample of the composite material (SDR and bulk-fill) was packed in a mold of 2, 4, and 6 mm. The curing light (QTH) of optimal intensity was exposed for 20 s at 220 volts over each sample, after which the specimen was taken out of the mold. The composite on the nonexposed end was scraped with a flat plastic instrument using gentle force. This remaining material was measured using a digital Vernier caliper. The reading was divided by half to follow the ISO 4049 method of measuring the depth of cure. Three readings per sample were generated and their mean was taken. The same procedure was repeated with 180 volts. A voltage converter was used to step-down the voltage. The study flow diagram is depicted in Figure 1 and armamentarium is shown in Figures 2 and 3.

Data analysis

SPSS version 20.0 (IBM SPSS Statistics software, New York, USA) was used for data analysis. Mean and standard deviation of continuous variable, i.e., the depth of cure (in mms) were computed. Independent sample *t*-test and factorial design ANOVA were applied to compare the depth of cure of the two composites at different voltages and increment thickness, respectively. Linear regression analysis was applied treating the depth of cure as an outcome variable. The level of significance was kept at 0.01.

Results

Table 1 describes the depth of cure of the two materials at increment thicknesses of 2, 4, and 6 mm. At 2 mm, both SDR and Filtek cured to a mean depth of cure of 0.95 ± 0.03 mm. At 4 mm, SDR cured to a mean depth of 1.93 ± 0.04, whereas Filtek cured till 1.86 ± 0.26 mm. At 6 mm increment thickness, SDR cured to 2.92 ± 0.05 mm, whereas Filtek bulk-fill cured to a mean depth of 2.43 ± 0.29 mm. At 6-mm depth, the difference between the mean curing depths of the two restoratives came out to be statistically significant [Figure 4].

Table 2 shows the depth of cure of the two composites at 180 and 220 volts at different increment thicknesses. Table 3 shows the linear regression analysis. Increment thickness, voltage, and composite type accounted for 93% variation in the depth of cure, whereas increment thickness and voltage accounted for 92% variation in the depth

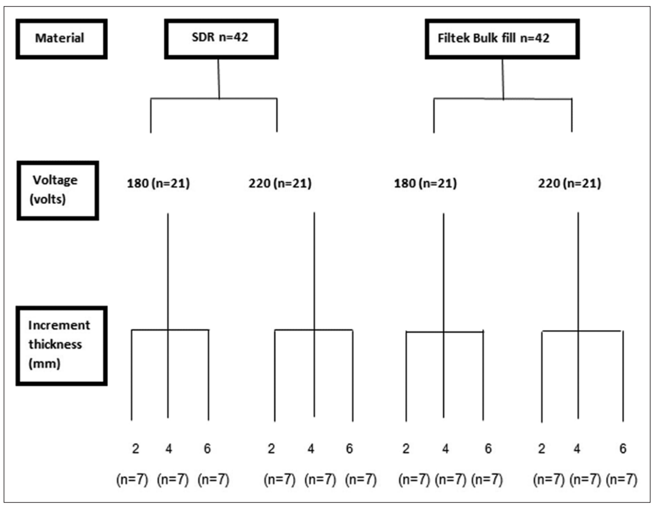

Figure 1: Study flow diagram

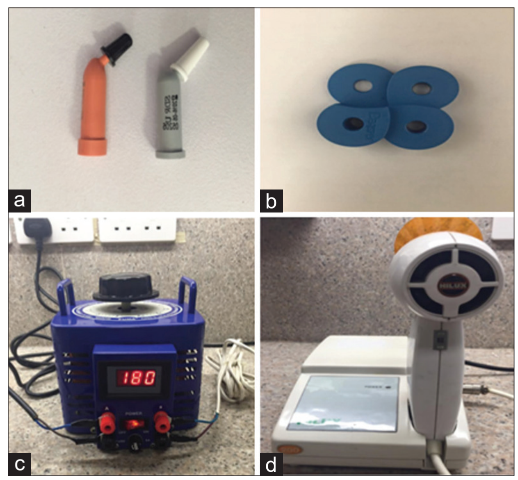

Figure 2: Armamentarium of the experiment. (a) Capsules of the Filtek bulk-fill and SDR restorative material. (b) Plastic molds for packing composites (2, 4, 6, 8 mm depth). (c) Voltage converter. (d) Quartz-Tungten– Halogen curing light

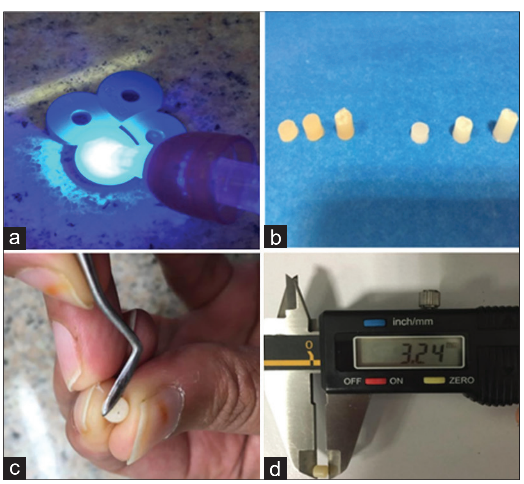

Figure 3: Data collection steps. (a) Curing the composite increment. (b) Cured samples of SDR and Filtek bulk-fill 2, 4 and 6 mm. (c) Scraping the composite according to the ISO 4049 method. (d) Measuring the depth of cure with a digital vernier caliper

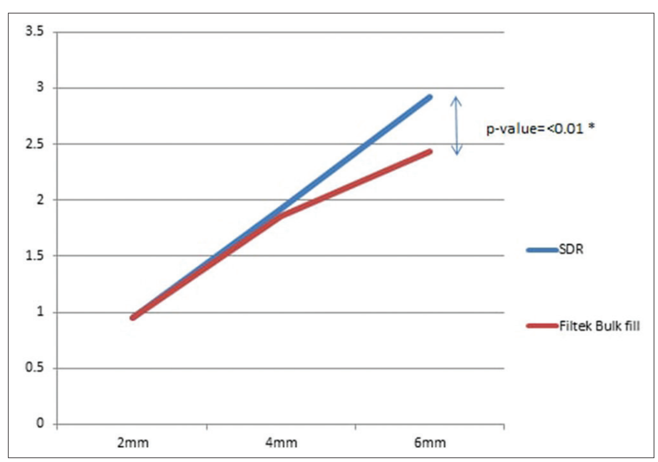

Figure 4: Depth of cure of the two materials at variable increment thickness. *Independent sample *t*-test reveals a statistically significant difference at 6 mm increment

Table 1: Depth of cure of the two materials at variable increment thickness

Increment thickness	Composite	*n*	Mean DOC (mm)	SD	*P*
2 mm	SDR	14	0.95	0.03	0.95
	Filtek	14	0.95	0.03	
4 mm	SDR	14	1.93	0.04	0.62
	Filtek	14	1.86	0.26	
6 mm	SDR	14	2.92	0.05	<0.01
	Filtek	14	2.43	0.29	

ANOVA was applied, DOC: Depth of cure assessed with ISO 4049 method and digital vernier caliper; SDR: Smart dentine replacement; SD: Standard deviation

Table 2: Depth of cure at variable voltage and increment thickness

Voltage (volts)	Composite	Increment thickness	*n*	Mean DOC (mm)	SD	*P*
180	SDR	2	7	0.95	0.02	0.51
		4	7	1.95	0.41	
		6	7	2.89	0.04	
	Filtek	2	7	0.95	0.04	
		4	7	1.88	0.08	
		6	7	2.17	0.05	
220	SDR	2	7	0.94	0.04	
		4	7	1.92	0.04	
		6	7	2.96	0.03	
	Filtek	2	7	0.94	0.04	
		4	7	1.84	0.36	
		6	7	2.70	0.12	

Factorial design ANOVA was applied; DOC: Depth of cure (mm); SD: Standard deviation; SDR: Smart dentine replacement

Table 3: Regression analysis

Model	*R*	R^2	Adjusted R^2	SE
Increment thickness	0.95	0.91	0.91	0.22
Increment thickness + voltage	0.95	0.92	0.92	0.22
Increment thickness + voltage + composite type	0.96	0.93	0.93	0.22

Linear regression analysis was applied, DOC was taken as outcome variable. SE: Standard error; DOC: Depth of cure (mm)

of cure. Increment thickness alone accounted for 91% variation in depth of cure of the composites.

Discussion

ISO 4049 method was used to assess the depth of cure in this study. Several other methods are also available for testing the depth of cure. These include employing with microhardness tests, scraping, and visual inspection. Infrared spectroscopy and laser are considered as direct methods.[23] ISO 4049 is a scraping test and is of qualitative nature where to be tested resin composite is first filled in a mold and then light cured. After curing, it is pushed out of the mold, and the uncured resin composite material on the bottom is then scraped with some instrument leaving a hard specimen. After scraping, the final measurements are taken and divided by 2. The resulting value is recorded as the depth of cure and represents the maximum set material. The rationale for dividing by two is that not all the hardened specimen is actually optimally cured. However, overestimation of the depth of cure is likely to occur with this method compared to the other methods.

Flury *et al*. studied four flowable composites and concluded that for bulk-fill materials the ISO 4049 method overestimated the depth of cure compared to Vickers hardness profiles.[24] Moore *et al*. performed a study on flowable, hybrid and packable composites of different shades and also concluded that the ISO 4049 method overestimates the depth of cure.[25] Nevertheless, this test is fairly simple to perform as no special equipment is needed and it's inexpensive; that is why it is commonly used in the assessment of the depth of cure.[26]

The study showed no significant differences of depth of cure among the two composites, i.e., SDR and Filtek bulk-fill flowable at 2 and 4 mm. However, at 6-mm bulk SDR cured significantly better than Filtek bulk-fill. Possible explanation for this observation could be the lighter shade of SDR compared to Filtek bulk-fill. The translucency of dental materials is affected by the difference in the refractive indices between the filler particles and the resin matrix which determines how light is scattered within the material.[27,28] Garoushi *et al.* employed ISO 4049 method to measure depth of cure composite in 10-mm cylinders. They observed for SDR, it was 4.3 ± 0.30 mm and for Filtek bulk-fill, it was 4.7 ± 0.15 mm.[17]

The greater depth of cure of the bulk-fill composites might be attributed to more efficient initiator systems and higher translucency of these composites.[24] Depth of cure of bulk-fill materials vary with translucency and viscosity, both of which depend on the filler content.[29] Finan *et al*. assessed the depth of cure of bulk-fill composites using three different techniques, i.e., Vickers hardness number, Fourier transform infrared spectroscopy, biaxial flexure strength, and concluded that bulk-fill flowable composite bases have a depth of cure over 4 mm.[30] Goracci *et al.*[31] and Campos *et al.*[32] also revealed that bulk-fill variety of flowable composite can predictably be cured beyond 4 mm. Jang *et al.*[33] showed that although SDR cured adequately at 4 mm but underwent considerable shrinkage compared to control material.

Garcia *et al.*[34] reported the mean depth of cure of SDR composites was 5.01 ± 0.03 mm using the ISO scraping method. They used 10 composite samples of 10 mm molds and cured for 20s. Alrahlah *et al.*[35] studied the depth of cure of bulk-fill composites and found out that Filtek bulk-fill cured to a depth of 4.14 ± 0.28 mm as determined by Vickers hardness profiles. Alshali[36] showed that the degree of conversion SDR was better than the Filtek bulk-fill at 24 h postcure period.

In the present study, both composites cured less deep at 180 volts than at an optimal voltage of 220 volts. However, the difference was not statistically significant. At both voltages, SDR performed better than Filtek bulk-fill. Appropriate curing light intensity and voltage are known as critical factors in the degree of conversion of the composite resins. The distance between the curing light tip and the composite material is also crucial.[37] In a study done on microhybrid composites, the influence of voltage and thickness was nearly 62% on the depth of cure.[26] However, in the present study where bulk-fill flowable composites are used, these two variables had 93% impact on the depth of cure. This reveals that voltage fluctuation has no significant bearing on the depth of cure in bulk-fill materials. As electrical voltage fluctuation is a frequent observation in developing countries such as Pakistan, this has an important implication on the performance and longevity of bulk-fill composites.

QTH light was used in this study as it is more commonly available, and the investigators wanted to see the relationship of voltage drop which cannot be assessed by LED types of lights. Dunn and Bush[38] demonstrated that QTH type curing units resulted in significantly harder top and bottom surfaces of the resin-based composite than did the LED units. Jandt *et al.*[39] confirmed that the mean depth of cure is 20% deeper among composite exposed with QTH light than achieved with LED unit.

The limitations of the present study are that only two varieties of bulk-fill restorative materials were compared. Only QTH light was used. No thermo-cycling was done; lack of which removes the effects of mechanical and thermal stresses that are otherwise inevitable in the oral environment and finally, only ISO 4049 method was employed to assess the depth of cure.

Conclusions

- No statistically significant difference was seen between SDR and Filtek bulk-fill for the depth of cure at 2 and 4 mm increments. At 6 mm increment, however, SDR cured significantly deeper than the Filtek bulk-fill
- SDR showed the consistently better depth of cure at lowered voltage compared to Filtek bulk-fill
- Of all variables, increment thickness has the greatest effect on depth of cure while changes in voltage have a minimal bearing on the depth of cure.

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Conflicts of interest

There are no conflicts of interest.

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