Comparative Evaluation of Depth of Cure between Two Bulk-fill Composites and a Conventional Resin Composite: An *In Vitro* Study

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ABSTRACT

Aim and objective: To evaluate and compare the depth of cure of two bulk-fill composites with a conventional composite.

Materials and methods: A sample size of 36 was taken and divided into three groups based on the type of composite. Standardized cylindrical stainless steel molds were prepared with 8 mm diameter and 10 mm depth. Measurement of depth of cure by the scraping method was performed according to the ISO 4049 (2009). After placing the specimens, the mold was pressed with polyester strips covered by glass slides and curing was initiated using Bluephase 20i (Ivoclar Vivadent US) light-curing unit through the glass slide. Immediately after curing, the specimens were removed from the mold and the uncured part of the specimens was removed by scraping with a plastic spatula. The absolute length of the hardened composite specimen was measured using a digital vernier caliper. The measured length was divided by two and recorded as the ISO depth of cure.

Results: The depth of cure of the composite specimens was found to be higher for Voco Xtra Fil bulk-fill composite than for Shofu Beautifil bulk-fill composite and Filtek Z350 XT conventional composite (3M/ESPE).

Conclusion: Within the limitations of the study, it can be concluded that the placement of bulk-fill composites with 3-mm increments is mandatory for complete curing.

Clinical significance: Depth of cure of bulk-fill composites determines the adaptation of restoration to the tooth structure, and this study aims to evaluate two newly introduced bulk-fill composites using scrape test.

Keywords: Bulk-fill composites, Conventional composite, Depth of cure, Polymerization shrinkage.

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INTRODUCTION

Dental composites are the most widely used direct tooth-colored esthetic restorative materials. For many decades, composite resin restorations were considered as a suitable restorative choice for anterior teeth.¹ However, current advances in their mechanical properties along with advancements in adhesive systems have broadened their application in posterior restorations.² The conventional methods of composite restoration are, however, time-consuming and technically challenging as they require incremental filling technique for complete polymerization of the material. Time-saving restorative materials are an ongoing demand for posterior applications. Hence, bulk-fill resin composites (BFRCs) have been introduced in the market to improve the efficiency of restorative procedures.³

The depth of cure is defined as the thickness of a resin that may be converted from a monomer to polymer at a specific light-curing condition.⁴ Studies have reported that bulk-fill composites can be filled and cured up to 4-mm thickness in a single increment without affecting polymerization shrinkage, degree of conversion, and cavity adaptation.⁵ When composite resin is cured in a single bulk layer, there may be a reduction in the degree of polymerization at the deeper portion due to the attenuation of the light. Uncured composite resins at the base of the restoration may cause polymerization shrinkage, secondary caries, pulpal irritation, and postoperative sensitivity.⁶ Therefore, the depth of cure during the placement is a major issue faced by bulk-fill composite resins. There are only limited studies investigating the depth of cure of bulk-fill composites. The purpose

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of this study was to evaluate the depth of cure of two bulk-fill composites and compare it with a conventional composite.

AIM AND OBJECTIVE

To evaluate and compare the depth of cure of two bulk-fill composites with a conventional composite.

SAMPLE SIZE ESTIMATION

Sample size is estimated using the formula

$$n = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2 \times \sigma^2}{d^2}$$

where $Z_{1-\alpha/2}$ is the value of Z at significance level 5%, $Z_{1-\beta}$ is the value of Z at power 95%, σ is the standard deviation of the population, and d is the difference between the means.

The effect size is 0.7.

Actual power = 0.9574.

A sample size of 12 per group was calculated using the above formula.

MATERIALS AND METHODS

Standardized cylindrical stainless steel molds were prepared with 8 mm diameter and 10 mm depth. A sample size of 36 was taken and divided into three groups based on the type of composite (Table 1).

Measurement of depth of cure by the scraping method was performed according to the ISO 4049 (2009) (International Organization for Standardization for polymer-based restorative materials).⁶ Vaseline was applied to the mold for the easy removal of composite resin from the mold. After placing the specimens (Fig. 1), the mold was pressed with polyester strips covered by glass slides and curing was initiated using Bluephase 20i (Ivoclar Vivadent US) light-curing unit (light intensity up to 2,000 mW/cm²) through the glass slide (Fig. 2). Immediately after curing, the specimens were removed from the mold and the uncured part of the specimens was removed by scraping with a plastic spatula (Fig. 3). The absolute length of the hardened composite specimen was measured using a digital vernier caliper (Figs 4 and 5). The measured length was divided by two and recorded as the ISO depth of cure.

STATISTICAL ANALYSIS

The ISO depth of cure of each group was analyzed by one-way ANOVA and Tukey's post hoc test using SPSS version 24.

Fig. 2: Curing was initiated using Bluephase 20i (Ivoclar Vivadent) light-curing unit

Fig. 1: Composite materials

Fig. 3: Uncured part of the composite specimen

Table 1: Composite materials and their composition

Composites	Matrix composition	Filler % by weight	Recommended thickness	Recommended curing time and light intensity	Manufacturer (country)
Beautifil bulk-fill	Bis-GMA, UDMA, Bis-MPEPP, TEGDMA, S-PRG filler based on fluoroboroaluminosilicate glass, polymerization initiator, pigments, and others	87	4 mm	10 sec ≥1,000 mW/cm ²	Shofu (Kyoto, Japan)
Voco Xtra Fil bulk-fill	Inorganic filler in a methacrylate matrix (Bis-GMA, UDMA, and TEGDMA)	86	2 mm	10 sec ≥1,000 mW/cm ²	VOCO, GmbH, Germany
Filtek Z350 XT	Bis-GMA, UDMA, TEGDMA, PEGDMA, Bis-EMA resin, silica filler, zirconia/silica cluster filler	82	4 mm	20 sec 400–1,000 mW/cm ² 10 sec 1,000–2,000 mW/cm ²	3M/ESPE (St Paul, MN, USA)

Fig. 4: Remaining part of the specimen

Fig. 5: Absolute length was measured using digital vernier caliper

RESULTS

The mean depth of cure of the composite specimens was found to be higher for Group B [4.795 mm] than for Group A [3.05 mm] and Group C [2.288 mm] as shown in Table 2.

The depth of cure between the investigated materials was highly significant with p -value < 0.05 (Table 3). The bar diagrams of depth of cure of the three composite materials are presented in Figure 6. Tukey's post hoc analysis showed a statistically significant difference between all the three groups as depicted in Table 4.

DISCUSSION

The current study showed variation in the depth of cure between the three composites determined by the ISO 4049 method. The bulk-fill materials, namely Voco Xtra Fil and Shofu Beautifil true to their name, demonstrated higher depth of cure than the conventional composite. The conventional composite deals with incremental technique, which involves the placement, adapting, and curing of composite materials in several layers of less than 2-mm increments each due to depth of cure issues.⁷ In this study, Filtek Z350 XT conventional resin composite was placed in increments and its organic matrix composition includes Bis-GMA,

Table 2: Depth of cure obtained by ISO scraping test

Groups	N	Mean	Std. deviation	Minimum	Maximum
Beautifil bulk-fill (Group A)	12	3.0583	0.15544	2.86	3.28
Voco Xtra Fil (Group B)	12	4.7958	0.12979	4.59	4.97
Filtek Z350 XT (Group C)	12	2.2883	0.09980	2.14	2.44
Total	36	3.3808	1.07116	2.14	4.97

Table 3: Statistical analysis using one-way ANOVA

	Sum of squares	df	Mean square	F	Sig.
Between groups	39.597	2	19.799		
Within groups	0.561	33	0.017	1165.410	0.000
Total	40.158	35			

Table 4: Tukey's post hoc analysis for comparison of depth of cure

(I) Group	(J) Group	Mean difference (I-J)	Std. error	Sig.
Beautifil bulk-fill	Voco Xtra Fil	-1.73750*	0.05321	0.000
	Filtek Z350 XT	0.77000*	0.05321	0.000
Voco Xtra Fil	Beautifil bulk-fill	1.73750*	0.05321	0.000
	Filtek Z350 XT	2.50750*	0.05321	0.000
Filtek Z350 XT	Beautifil bulk-fill	-0.77000*	0.05321	0.000
	Voco Xtra Fil	-2.50750*	0.05321	0.000

* denotes that the mean difference is significant at the 0.05 level.

UDMA, TEGDMA, PEGDMA, Bis-EMA resin, silica filler, and zirconia/silica cluster filler with 82% filler particles by weight. They are approximately 0.004–10 μ m in size and are based on silica and zirconia filler type. The bulk-fill composite (Voco Xtra Fil) showed a depth of cure of 4.79 mm, whereas for conventional composite, it was 2.29 mm, and there was a statistically significant difference. The higher depth of cure of bulk-fill composites may be due to the present modifications on their particle content, being more translucent and permitting better light penetration into deeper layers.⁸ Most bulk-fill composites contain camphorquinone as the

Fig. 6: Graphical representation of depth of cure

primary photoinitiator and a tertiary amine as coinitiator.⁹ In an *in vitro* study by Moharam et al., 4- to 5-mm-thick bulk-fill dental resin composites, Xtra Fil and SonicFill materials, showed adequate depth of cure.¹⁰

The bulk-fill composite (Beautifil Shofu Japan) did not achieve a 4 mm depth of cure. This could be due to material differences, such as shade, type of photoinitiators, and curing, which could vary with different materials. The matrix composition includes Bis-GMA, UDMA, Bis-MPEPP, TEGDMA, polymerization initiator, and pigments. They have surface pre-reacted glass-ionomer filler based on fluoroboroaluminosilicate glass particles with 87% by weight. In this study, the depth of cure of Beautifil bulk-fill composite was similar to that of results obtained by Yap et al. done using scrape test.¹¹ However, due to varied composition, handling properties, and different physical properties, some of the bulk-fill composites failed to cure up to 4 mm.¹² These materials may, however, be associated with increased internal gap formation and lower physical and mechanical properties.¹³

Among the bulk-fill composites used, Voco Xtra Fil bulk-fill composite showed greater depth of cure than the other two composites. The Voco Xtra Fil bulk-fill composite is a newer composite based on multihybrid technology. By optimizing the filler sizes, the material achieves an extremely high filler degree of 86%.¹⁴ The organic matrix composition consists of inorganic filler in a methacrylate matrix (Bis-GMA, UDMA, and TEGDMA) and is based on barium aluminum silicate glass.

The Bluephase 20i (Ivoclar Vivadent US) used in this study has the highest light intensity (up to 2,000 mW/cm²) with extremely short curing times of no more than 5 seconds for light and dark composites. The wavelength of this LED curing light ranges from 385 to 515 nm.

A number of different techniques have been employed to measure the depth of cure. These include scraping away the unset materials by using plastic spatula and measuring the remaining specimen, measuring the top and bottom hardness ratio, and measuring the top and bottom degree of conversion of double bonds in the polymer.¹⁵ In this study, scraping technique has been used as the depth of cure measure according to the ISO standard for dental resin 4049 and has been considered as a standard test.¹⁶

The parameters used in this experiment are probably conservative compared to actual clinical situations. The 1-mm

distance (glass slide between resin and light tip) between the light tip and resin surface is probably the minimum, and the clinical feasibility has to be evaluated.¹⁷ This study evaluated the depth of cure of only two bulk-fill composites and compared it with a conventional composite, which is a limitation with respect to generalizing the conclusions. Besides these, we have to conduct *in vivo* studies too to identify the relationship between depth of cure of bulk-fill resin-based composites and its associated factors including degree of conversion and cytotoxicity.

CONCLUSION

Within the limitations of the study, it can be concluded that the placement of bulk-fill composites with 3-mm increments is mandatory for complete curing.

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