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Depth of Cure and Mechanical Properties of Bulk-Fill Posterior Dental Composites

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ABSTRACT

The objectives of this study were to compare the microhardness, flexural strength and compressive strength of a new bulk-fill composite (SonicFill™) to a conventional nanohybrid composite (Herculite Precis) and an established bulk-fill composite (Tetric N Ceram). In addition, the depth of cure of the two bulk-fill resin composites was also investigated. The materials were prepared and tested for the mechanical properties following ISO 4049:2009. Microhardness and depth of cure were measured using Vickers hardness tester. Compressive and flexural strength were tested using a universal testing machine. To determine the depth of cure, microhardness of the bulk-fill composites were measured as a function of selected depth of materials at 0.5 mm, 2.0 mm and 4.0 mm. Data were analyzed by either one-way ANOVA or Friedman test. Analysis demonstrated that SonicFill™ gave the highest microhardness value (101.8 $\pm$ 4.6 VHN) compared to the other two groups. There were no significant differences among all groups in flexural and compressive strength. The depth of cure decreased as the thickness of both bulk-fill composites increased. In conclusion, SonicFill™ showed favorable mechanical properties compared to other composites tested. In both bulk-filled groups, microhardness value decreased as the thickness of the composite increased. The polymerization of the bulk-filled composites was effective only at 2 mm or less.

Keywords: Bulk-fill composite, compressive strength, depth of cure, flexural strength, microhardness

INTRODUCTION

Since the introduction of dental composites into the dental market more than 40 years ago, many efforts and studies have been made to improve their clinical behavior (1-5). Unlike amalgam, placement of dental composites in a cavity preparation needs meticulous attention or it may fail prematurely. Incremental layering technique has been accepted as a standard protocol for placement of dental composites to ensure adequate light curing and reduce polymerization shrinkage (2). However, this technique has several weaknesses such as the possibility of incorporating voids or contamination between dental composites layers, difficulty in placement because of limited access to the cavity, and time consuming (3). Several manufacturers have introduced innovative bulk-fill dental composites that can be applied to the cavity in a single increment or in thickness up to 5 mm with enhanced curing and controlled shrinkage (4). The latter is achieved by means of novel resins, special modulators, unique fillers and filler control (6-8). The mechanical properties of bulk-fill composites have been the subject of some disagreement. While some authors have reported lower mechanical properties than conventional composites, others have stated otherwise (9-11).

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The extend of polymerization of bulk-fill composites at various depth (or depth of cure) has been studies widely using several techniques. One of them is advocated by the ISO standard for dental composites 4049 (12), where the unset material is scrapped immediately after irradiation. The length of the set specimen is then measured and divided by two (13). Another technique involved measuring the hardness of the top and bottom specimen surfaces (14), or the degree of conversion (15). Optical microscopy has also been used (16), where the boundary between cured and uncured material is visualized under microscope. The surface microhardness of resin composites has been used to evaluate indirectly the extent of polymerization, and also the efficiency of the light cure unit (16, 17). Due to low light irradiance passing through resin composites, the degree of conversion reduces and as a result, microhardness decreases with increasing depth (17).

Although current resin composites have adequate mechanical properties for them to be used in anterior and posterior teeth, concern still exists when direct composites are placed in high stress situations, such as in patient with parafunctional habits (18). Posterior composites require adequate strength and wear resistance to endure mastication forces. Recently, a new bulk-fill posterior composite, SonicFill™ (Kerr, USA) has been introduced in the market. The SonicFill™ system consists of a handpiece that delivers sonic energy at varying intensities, which is adjustable to control rate of composite extrusion. The composite incorporates modifiers that react to sonic vibrations to alter the viscosity of the material. The sonic energy reduces the viscosity of the resin by 87 % allowing adaptation in deep cavities, up to 5 mm, in a single increment. When the sonic energy ceases, the resin returns to its high viscosity state, facilitating sculpting and carving to the desired anatomical form.

Studies on this innovative bulk-fill composite system are limited. Therefore, the objectives of this study were to compare the microhardness, flexural strength and compressive strength of SonicFill™ (Kerr, CA, USA) to a conventional nanohybrid composite [Herculite Precis (Kerr, CA, USA)] and an established bulk-fill composite [Tetric N Ceram (Ivoclar Vivadent Inc., NY, USA)]. In addition, the depth of cure of the two bulk-fill resin composites was also investigated. The null hypothesis was that there are no differences in the mechanical properties in all materials tested. In addition, there is no difference in depth of cure between the two bulk-fill composites.

MATERIALS AND METHODS

The materials evaluated and their technical profiles are presented in Table 1. The methodology was divided into four parts *(i-iv).*

Table 1: Materials, manufacturer, chemical composition of matrix and filler as well as filler content by weight (wt. %) and volume (vol. %)

Group	Material (Manufacturer)	Resin matrix	Filler	Filler wt.%/vol%
1 (Control)	Herculite Precis (Kerr, CA, USA)	Bis-GMA, TEGDMA	Al–Ba–Si glass, dispersed SiO_2, 0.6 µm mean size	78.4 / 59
2 (Bulk-fill)	Tetric N Ceram (Ivoclar Vivadent Inc., NY, USA)	Bis-GMA, UDMA	Ba-Al-Si-glass, Prepolymer filler (monomer, glass filler and ytterbium fluoride), spherical mixed oxide	79-81 (including 17% prepolymers) / 60-61
3 (Bulk-fill)	SonicFill (Kerr, CA, USA)	Bis-GMA, TEGDMA	SiO_2, glass, oxide	83.5/-

(i) Vickers microhardness measurement

Ten disc-shaped specimens (10 x 2 mm) from each material were fabricated using customized stainless steel mold. The composites were placed in one increment and excess materials were removed by compressing the mold with mylar strips and glass slides. The top surface of the composite specimens were light polymerized for10s each using a LED curing light (Demi Plus, Kerr, CA, USA) with a wave length of 450-470nm and irradiance of 1330 mW/cm^2. The glass slide was removed and the composite specimens were light cured for another 10s. The mylar strip were subsequently discarded and the composite discs were removed from the mold. Any minor material excess were gently removed with Sof-Lex (3M ESPE, St Paul, MN, USA) fine polishing discs. The specimens were kept in an incubator for 7 days at 37°C prior to testing. For microhardness measurement, a 100 g load was applied for 10 s on the upper surface of the disc using a microhardness tester (Shimadzu Corp., Kyoto, Japan). Five Vickers hardness number (VHN) were obtained from each sample.

(ii) Depth of cure investigation

Ten specimens from each bulk-fill materials were prepared in customized stainless steel mold with a slot

dimension of 2 x 3 x 7 mm, and a top plate (Figure 1). The mold was overfilled with composite, and a mylar strip was placed on top of the material with the top plate subsequently pressed into position, followed by the scraping of the excess material from the entrance of the mold. The molds were irradiated from one end only. Each specimen was light polymerized for 40 s using a LED curing light (Demi Plus, Kerr, CA, USA). All specimens were stored dry in an incubator at 37 °C for 48 h prior to measurement. The VHN was measured as a function of depth of material (0.5, 2.0 and 4.0 mm) using a microhardness tester (Shimadzu Corp., Kyoto, Japan). A fixed load of 50 g was applied for 10 s. Five VHNs were obtained from each depth. Data were calculated as hardness numbers and accordingly plotted as hardness versus depth profiles.

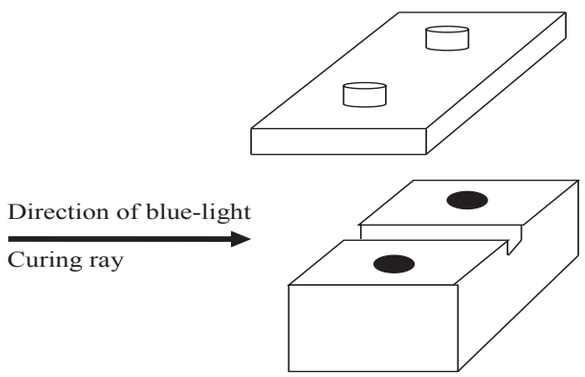

Figure 1: Schematic diagram of stainless steel mold for depth of cure measurement with top cover plate

(iii) Flexural strength analysis

Ten beam-shaped specimens (2 x 2 x 25 mm) from each material were fabricated using customized stainless steel mold. The composites were placed in one increment and excess materials were removed by compressing the mold with mylar strips and glass slides. The top surface was light polymerized for 10s at three different places (left-middle-right). Glass slide was removed and composite was light-cured for another 30s. Mylar strip was discarded and composite beam was taken out. The bottom surface was light-cured for 40s. The excess was removed gently with Sof-Lex (3M ESPE, St Paul, MN, USA) fine polishing discs. The final dimensions of the specimens and the parallelism between their opposite surfaces were verified with a digital caliper (Mitutoyo Corp., Kawasaki, Japan). The specimens were kept in an incubator for 24 hours at 37°C prior to testing.

The flexural strength (σ_f) was measured using a three-point bend test. Samples were loaded in a universal testing machine (Shimadzu Corp., Kyoto, Japan) with a load cell of 5 kN and crosshead speed of 1.0 mm/min until fracture occurred.

(iv) Compressive strength analysis

Ten cylindrical-shaped specimens (4 x 8 mm) were prepared for each group using customized stainless steel mold. The sample preparations were similar as in *(i)* except that the material was placed in several increments inside the mold. The specimens were then taken out from the mold and light polymerized at the bottom and mid-section of the specimens. The specimens were then kept in an incubator for 24 hours at 37°C prior to testing. All specimens were transferred to the universal testing machine (Shimadzu Corp., Kyoto, Japan) and were subjected to compressive strength analysis at a load cell of 5kN and crosshead speed of 1.0 mm/min.

Statistical Analysis

SPSS statistical program (Version 12.0.1, SPSS Inc., Chicago, USA) was used to analyze the data. Descriptive data were expressed as mean [± standard deviation (SD)]. Numeric values were compared with one-way ANOVA or Friedman test, where appropriate. Post-hoc test was performed for further multiple comparison and the results were reported with a Bonferroni method adjustment. All statistical analyses were carried out at significance level 0.05.

RESULTS

The mean average VHN is shown in Figure 2. Normality assumption was made and statistical analysis was performed using one-way ANOVA test. SonicFill™ gave the highest overall mean VHN (101.8 ± 4.6), whereas Tetric N Ceram gave the lowest mean VHN (68.1 ± 4.7). The VHN for all groups were found to be significantly different (p = .000). Multiple group comparison was done using post-hoc test with Bonferroni correction (p < .0167) showing all pairs were significantly different.

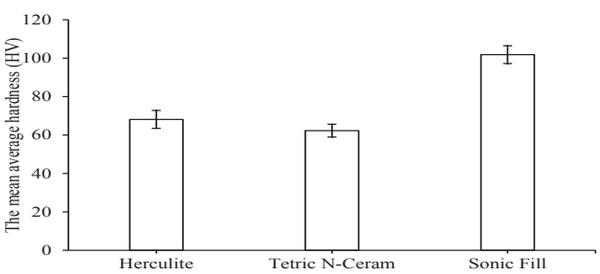

Figure 2: Mean VHN for each group

The mean average VHN in increasing depth of cure for the two groups of bulk-fill composites (Tetric N Ceram and SonicFill™) is illustrated in Figure 3. For both groups, VHN decreased at increasing depth. Statistical analysis was performed using Friedman test. The mean average VHN in all curing depths were differed significantly ($p = 0.000$). Pairwise comparison using post-hoc test with Bonferroni adjustment ($p < .0167$) was done. All pairs of measurement depths in SonicFill™ were significantly different; (0.5 mm and 2.0 mm, $p = .003$; 0.5 mm and 4.0 mm, $p = .000$; 2.0 mm and 4.0 mm, $p = .001$). Similar results were observed in Tetric N Ceram group; (0.5 mm and 2.0 mm, $p = .002$; 0.5 mm and 4.0 mm, $p = .002$; 2.0 mm and 4.0 mm, $p = .002$).

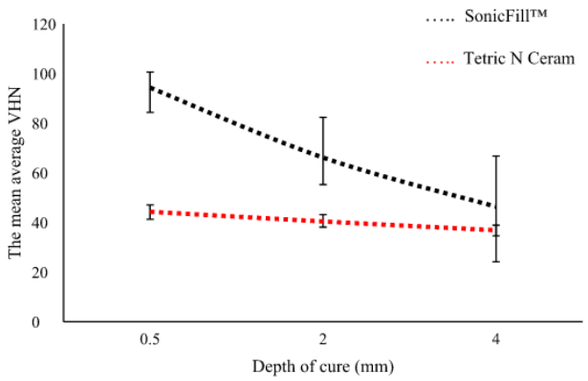

Figure 3: The mean average hardness in increasing curing depths

Both the mean average values with standard deviation for flexural and compressive strength are shown in Figure 4. Tetric N Ceram showed the superior flexural strength value followed by SonicFill™ and Herculite. For flexural strength data, normality assumption was made and statistical analysis using one-way ANOVA test was done revealing significantly different ($p = .029$) among all the groups of composite resin. However, analysis done using Dunnett's T3 multiple comparison showed that all pairs were not significantly different ($p > .05$). Similar analysis was done for the compressive strength data. The mean average compressive strength was found to be not significant. The compressive strength was seen highest in SonicFill™ and lowest in Tetric N Ceram.

DISCUSSION

This *in vitro* study investigated the mechanical properties of a new bulk-fill composite, SonicFill™, and compared it with a conventional nanohybrid composite and an established bulk-fill composite system. The methods used in this study followed the ISO 4049:2009, therefore, the results obtained

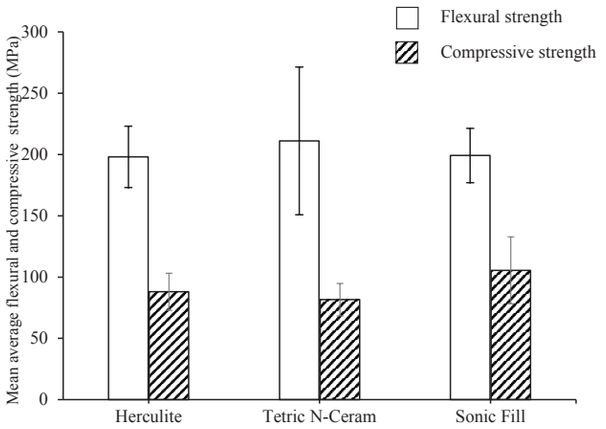

Figure 4: The mean average flexural strength and compressive strength

can be compared with other studies in the dental composite field.

The methodology in this research was divided into four sections. In the first part of this study, the microhardness of the composites was tested. The result showed that the new bulk-fill composite gave the highest VHN. This could be attributed to the percentage of filler content as shown in Table 1. SonicFill™ has the highest filler wt% as compared to the two groups. Previous studies found a positive correlation between filler loading and mechanical properties (19).

In the second part of this experiment, the depth of cure was determined. Scraping method is another method to investigate the depth of cure. However, in this study, we only focused on the measurement of the hardness using microhardness tester. Three different depths were selected: 0.5 mm, 2 mm and 4 mm. The depth of 0.5 mm was used as a control whereas the 2 mm is a maximum thickness for incremental placement of conventional resin composite in a cavity preparation. SonicFill™ is claimed to be able to fully polymerize at 5 mm depth by the manufacturer. However, manufacturer of Tetric N Ceram, claimed that their material can only be fully polymerized at 4 mm depth. Therefore, in the depth of cure analysis, microhardness at 4 mm depth was selected. The results showed that at 0.5 mm depth, the microhardness of both bulk-fill composites were higher compared to microhardness at 2 mm and 4 mm depth. The further the distant from the light curing source result in a decrease of the degree of conversion and also the mechanical properties of the composite (20). In our pilot study, all conventional composite specimens were not able to polymerize beyond 2 mm depth. Therefore, the depth of cure analysis was not carried out on the conventional composite.

Flexural strength can determine the longevity of restoration towards chewing pressure and occlusal forces. Moreover, it is one of the mechanical properties of ISO for screening of resin-based materials (21). Meanwhile, compressive strength is also involved in chewing action since several of masticatory forces are of compressive nature (21). According to the ISO standards, composite materials should have a minimum flexural strength of 80 MPa (12). Our study has shown that all three groups gave flexural strength higher than the ISO limit. Both bulk-fill composites have comparable flexural strength value with the conventional composite. In this case, the filler loading did not play a major role in the determination of flexural strength.

For the final part of this study, the compressive strength was investigated. Similar with the flexural strength outcome, there were no significant differences among all the composites tested. All composites gave the compressive strength in the range of 88 to 105 MPa. However, these results were lower compared to previous studies (22, 23).

Overall, based on the results of this study, SonicFill™ can be recommended for dental practitioners for posterior restoration. The potential convenience of sonic placement and the advantage of the reduction in viscosity would likely be operator-dependence preference. However, to improve polymerization of the bulk-fill composite, the distance between light curing source with the surface of composite should be the closest possible. In a Class II cavity with deep gingival seat, light curing should be done on both occlusal and interproximal directions.

It is important to highlight that all experiments were done under an ideal laboratory condition. Effect of environment such as moisture, saliva and temperature were not included. Therefore, the results have to be accepted with precaution. Further studies such as measurement of depth of cure using FTIR and other laboratory and clinical studies on bulk-filled materials are needed to confirm these findings.

CONCLUSION

Within the limitation of the present study, it can be concluded that SonicFill™ showed favorable mechanical properties (microhardness, flexural strength and compressive strength) compared to other composites tested. In both bulk-filled groups, microhardness value decreased as the thickness of the composite increased. The polymerization of the bulk-filled composites was effective only at 2 mm or less. The null hypotheses were rejected.

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Declaration Of Interest

The authors report no conflicts of interest. The authors alone are responsible with the content of this article.

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