The effect of light curing tip distance on the curing depth of bulk fill resin based composites

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ABSTRACT

Background: This in vitro study measure and compare the effect of light curing tip distance on the depth of cure by measuring vickers microhardness value on two recently launched bulk fill resin based composites Tetric EvoCeram Bulk Fill and Surefil SDR Flow with 4 mm thickness in comparison to Filtek Z250 Universal Restorative with 2 mm thickness. In addition, measure and compare the bottom to top microhardness ratio with different light curing tip distances.

Materials and Method: One hundred fifty composite specimens were obtained from two cylindrical plastic molds the first one for bulk fill composites (Tetric EvoCeram Bulk Fill and Surefil SDR Flow) with 4 mm diameter and 4 mm depth, the second one for Filtek Z250 Universal Restorative with 4 mm diameter and 2 mm depth. Each spcimen was light-cured using WOODPECKER LED CURING LIGHT for 20 sec. Polymerization was performed with the light tip positioned in direct contact, 2 mm, 4 mm, 6 mm and 8 mm distant from the top surface of the sample. After one day of storage in distilled water in a light proof container at 37˚C, the hardness on the bottom and top surfaces of each specimen was tested using the Digital Micro Vickers Hardness Tester. Then the Data were analyzed statistically by ANOVA test, LSD test and t-test.

Results: All experimental groups show top microhardness higher than bottom microhardness with high significant difference with all light tip distances. At 0 mm light tip distance all groups give the highest microhardness value. Filtek Z250 Universal Restorative shows accepted bottom to top microhardness ratio at all light tip distances. Surefil SDR Flow shows accepted bottom to top ratio only at 0, 2 and 4mm light tip distances while Tetric EvoCeram Bulk Fill shows the bottom to top microhardness ratio less than the accepted value with all light tip distances.

Conclusion: From the results of this study we can conclude that the polymerization of bulk fill composite depends greatly on the distance from light curing tip, Tetric EvoCeram Bulk Fill composite not recommended to be used as bulk fill restoration in deep cavities and need further studies, while Surefil SDR Flow not recommended to be used in deep cavity when curing tip distance (6-8 mm), in addition we can conclude that the thickness of the increments is more important than light curing tip distance.

Key words: light cure tip distance, depth of cure, Tetric EvoCeram Bulk Fill composite, Surefil SDR Flow. (J Bagh Coll Dentistry 2014; 26(4):46-53).

INTRODUCTION

Curing depth often considered a primary factor for clinical success of composite resin restorations, since it directly affects the physical properties of materials and longevity of restorations. The factors that may affect the curing of resin materials include those related to the restorative material, including the resin shade, amount of photo initiators, organic and inorganic matrix; the operator, including the distance and orientation of light beams and restorative technique and types of light curing units, concerning the emission spectrum and association between light intensity, period of exposure and general status of the equipment [(1)].

Energy of the light emitted from a light-curing unit decreases drastically when transmitted through resin composite [(2)], leading to a gradual decrease in degree of conversion of the resin composite material at increasing distance from the irradiated surface.

Decreases in degree of conversion compromise physical properties and increase elution of monomer and thus may lead to premature failure of a restoration or may negatively affect the pulp tissue [(3)]. When restoring cavities with light-curing resin composites, it has therefore been regarded as the gold standard to apply and cure the resin composite in increments of limited thickness. The maximal increment thickness has been generally defined as 2 mm [(4)].

However, restoring cavities, especially deep ones, with resin composite increments of 2 mm thickness is time-consuming and implies a risk of incorporating air bubbles or contaminations between the increments. Thus, various manufacturers have recently introduced new types of resin composites, so-called “bulk fill” materials that are claimed to be curable to a maximal increment thickness of 4 mm [(5, 6)].

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An adequate polymerization of resin composites is crucial for the ultimate success and longevity of the restoration [7]. It depends not only on the irradiance of the curing light and irradiation time but also on the distance of the light tip from the tooth-restorative material [8,9]. Because the light intensity diminishes as the tip of the source light moves away from the resin composite's surface, the light-curing tip unit should be in direct contact with the restoration's surface. However, sometimes cavity design does not allow the polymerization within this distance [10].

The degree of monomer conversion of resin composites can be measured using different testing techniques, either directly or indirectly. Among the indirect methods, surface hardness testing has been used in many studies because it has been shown to be a good indicator of the degree of conversion [11].

MATERIALS AND METHOD

Sample grouping:

The total composite specimens were 150, divided into three groups, 50 specimens for each group named according to the type of composite used in this study. The first was Tetric EvoCeram Bulk Fill, the second was SureFil SDR Flow and the third was Filtek Z250 Universal Restorative. Then each group subdivided into five subgroups according to the light curing tip distance (0, 2, 4, 6, and 8 mm).

Preparation of composite resin specimens:

Total number of 150 Specimens was obtained from two cylindrical plastic molds. The first one for bulk fill composites, Tetric EvoCeram Bulk Fill, SureFil SDR Flow with 4 mm diameter and 4 mm depth, the second one for Filtek Z250 Universal Restorative with 4 mm diameter and 2 mm depth allowing the evaluation of the microhardness for the composite resin specimens at both top and bottom surfaces. All the composites were filled in the mold according to manufacturer instructions.

Each mold placed over the microscopic glass slide (1 mm thickness) and dental transparent strip, then the composite resin was loaded by injecting it directly from the tube into the mold cavity in order to reduce air voids [12]. The material was packed into the mold until the cavity was overfilled. Thereafter, the surface of the material was covered with another dental transparent strip and microscopic glass slide in order to produce a flat smooth surface and to prevent the formation of oxygen-inhibited layer on the surface of the samples. A (200 gm) pressure has been applied for 1 minute to expel excess material from the mold and to reduce voids [13]. The glass slide was removed and the composite resin was irradiated from the top through the celluloid strip in away that the distal end of the light curing machine tip was held without pressure in contact to the celluloid strip and the center was coincident with the Specimen's long axis [14].

Specimens' photo-polymerization:

Then, each specimen was light-cured using WOODPECKER LED CURING LIGHT with light intensity 850-1000 mW/cm² which was verified every 30 specimens before polymerization by using OPTILUX RADIOMETER. Each type of composite resin polymerized for 20 sec. according to the manufacturer instructions. Polymerization was performed with the light tip positioned in direct contact, 2 mm, 4 mm, 6 mm and 8 mm distant from the top surface of the sample, the distance were standardized using plastic rings that acted as spacers [10].

Sample Storage:

Immediately after curing of composite resin specimen, the celluloid strip was removed, the composite resin specimen was obtained then stored for 24 hours in a light proof container with distilled water at 37˚C to complete polymerization and inhibit any further polymerization from transient light [14].

Testing Procedure

After one day of storage in distilled water in a light proof container at 37˚C , the hardness on the bottom and top surfaces of each specimen was tested using the Digital Micro Vickers Hardness Tester TH714 (Beijing Time High Technology Ltd.). The specimens positioned beneath the indenter of the microhardness tester and the surface hardness of the specimens was measured with the microhardness tester using a load of 200 g load for 15 seconds to measure the Vickers Hardness Numbers (VHN) [15].

Each surface of the specimen was divided into 4 equal quadrants, on each surface, the top (turned to the light source) and the bottom (opposite of the light source) surfaces, one indentation took place for each quadrant and eight indentations were taken from each specimen. The hardness mean values were calculated for each surface [16].

RESULTS

The microhardness of Tetric EvoCeram Bulk Fill group:

Means and standard deviation of the top and bottom microhardness of Tetric EvoCeram Bulk Fill group at different light tip distances are summarized in (Table 1). A comparison of the microhardness of Tetric EvoCeram Bulk Fill group at different light tip distances by ANOVA test (F-test and p-value) are summarized in (Table 2).

Table 1: Descriptive statistics of the top and bottom microhardness of Tetric EvoCeram Bulk Fill group at different light tip distances

Distance (mm)	Top		Bottom	
	Mean	S.D.	Mean	S.D.
0	51.30	2.69	38.74	4.70
2	47.21	5.90	34.99	5.77
4	46.84	3.43	30.55	5.22
6	46.22	3.39	26.89	3.43
8	45.81	4.20	21.62	4.38

Table 2: Comparison of the top and bottom microhardness of Tetric EvoCeram Bulk Fill group at different light tip distances (ANOVA test)

	Surface	Sum of Squares	df	Mean Square	F-test	p-value
Between Groups	**Top**	194.30	4	48.57	2.93	0.031 (S)
Within Groups		745.77	45	16.57		
Total		940.07	49			
Between Groups	**Bottom**	1799.40	4	449.85	19.80	0.000 (HS)
Within Groups		1022.20	45	22.72		
Total		2821.60	49			

The top and bottom microhardness of Tetric EvoCeram Bulk Fill group showed that the highest microhardness value were at 0 mm light tip distance followed by 2 mm, 4 mm, 6 mm and 8mm light tip distances respectively.

Statistical analysis of the data by using one-way ANOVA test showed that there is a significant differences in the top and bottom microhardness of Tetric EvoCeram Bulk Fill group at different light tip distances (p=0.031). The LSD test of the top and bottom microhardness of Tetric EvoCeram Bulk Fill group at different light tip distances summarized in (Table 3).

Table 3: LSD test shows the mean differences and the P-value of the top and bottom microhardness among Tetric EvoCeram Bulk Fill groups.

Distance (mm)		Top		Bottom	
		Mean difference	p-value	Mean difference	p-value
0	**2**	4.088	0.085 (NS)	3.750	0.030 (S)
	4	4.454	0.000 (HS)	8.193	0.018 (S)
	6	5.079	0.000 (HS)	11.844	0.008 (HS)
	8	5.487	0.000 (HS)	17.123	0.004 (HS)
2	**4**	0.366	0.043 (S)	4.443	0.842 (NS)
	6	0.991	0.000 (HS)	8.094	0.589 (NS)
	8	1.399	0.000 (HS)	13.373	0.446 (NS)
4	**6**	0.625	0.094 (NS)	3.651	0.733 (NS)
	8	1.033	0.000 (HS)	8.930	0.573 (NS)
6	**8**	0.408	0.017 (S)	5.279	0.824 (NS)

The microhardness of SureFil SDR Flow group

Means, standard deviation, minimum and maximum values of the top microhardness of SureFil SDR Flow group at different light tip distances are summarized in (Table 4). A comparison of the top and bottom microhardness of SureFil SDR Flow group at different light tip distances by ANOVA test (F-test and p-value) are summarized in (Table 5).

Table 4: Descriptive statistics of the top and bottom microhardness of SureFil SDR Flow group at different light tip distances.

Distance (mm)	Top		Bottom	
	Mean	S.D.	Mean	S.D.
0	34.59	2.74	30.25	2.74
2	29.96	2.44	24.96	2.38
4	29.16	2.21	24.06	1.74
6	28.55	1.79	22.55	1.83
8	28.18	2.27	20.16	3.41

Table 5: Comparison of the top and bottom microhardness of SureFil SDR Flow group at different light tip distances (ANOVA).

	Surface	Sum of Squares	df	Mean Square	F-test	p-value
Between Groups	Top	271.18	4	67.79	12.70	0.000 (HS)
Within Groups		240.23	45	5.34		
Total		511.40	49			
Between Groups	Bottom	559.86	4	139.97	22.45	0.000 (HS)
Within Groups		280.57	45	6.23		
Total		840.43	49			

The top and bottom microhardness of SureFil SDR Flow group showed that the highest microhardness value were at 0 mm light tip distance followed by 2 mm, 4 mm, 6 mm and 8 mm light tip distances respectively.

Statistical analysis of the data by using one-way ANOVA test showed that there is a highly significant differences in the top and bottom microhardness of SureFil SDR Flow group at different light tip distances (p=0.000). The LSD test of the top and bottom microhardness of SureFil SDR Flow group at different light tip distances summarized in (Table 6).

Table 6: LSD test shows the mean differences and the P-value of the top and bottom microhardness among SureFil SDR Flow groups.

Light tip distances		Top		Bottom	
		Mean difference	p-value	Mean difference	p-value
0	2	4.628	0.000 (HS)	5.288	0.000 (HS)
	4	5.424	0.000 (HS)	6.183	0.000 (HS)
	6	6.034	0.000 (HS)	7.699	0.000 (HS)
	8	6.409	0.000 (HS)	10.083	0.000 (HS)
2	4	0.796	0.427 (NS)	0.895	0.445 (NS)
	6	1.406	0.036 (S)	2.411	0.180 (NS)
	8	1.781	0.000 (HS)	4.795	0.092 (NS)
4	6	0.610	0.181 (NS)	1.516	0.558 (NS)
	8	0.985	0.001 (HS)	3.900	0.346 (NS)
6	8	0.375	0.038 (S)	2.384	0.718 (NS)

The microhardness of Filtek Z250 Universal Restorative group:

Means, standard deviation, minimum and maximum values of the top and bottom microhardness of Filtek Z250 Universal Restorative group at different light tip distances are summarized in (Table 7). A comparison of the top microhardness of Filtek Z250 Universal Restorative group at different light tip distances by ANOVA test (F-test and p-value) are summarized in (Table 8).

Table 7: Descriptive statistics of the top and bottom microhardness of Filtek Z250 Universal Restorative group at different light tip distances.

Distance (mm)	Top		Bottom	
	Mean	S.D.	Mean	S.D.
0	112.02	10.86	94.06	9.98
2	108.89	21.59	91.20	18.38
4	105.71	12.34	87.07	10.56
6	104.49	20.91	85.29	2.75
8	84.75	4.50	68.26	5.53

Table 8: Comparison of the top and bottom microhardness of Filtek Z250 Universal Restorative group at different light tip distances (ANOVA test).

	Surface	Sum of Squares	df	Mean Square	F-test	p-value
Between Groups	**Top**	4586.85	4	1146.71	4.80	0.003 (HS)
Within Groups		10746.02	45	238.80		
Total		15332.87	49			
Between Groups	**Bottom**	4048.50	4	1012.13	8.62	0.000 (HS)
Within Groups		5284.98	45	117.44		
Total		9333.48	49			

The top and bottom microhardness of Filtek Z250 Universal Restorative group showed that the highest microhardness value were at 0 mm light tip distance followed by 2 mm, 4 mm, 6 mm and 8 mm light tip distances respectively.

Statistical analysis of the data by using one-way ANOVA test showed that there is a highly significant differences in the top and bottom microhardness of Filtek Z250 Universal Restorative group at different light tip distances (p=0.003). The LSD test of the top and bottom microhardness of Filtek Z250 Universal Restorative group at different light tip distances summarized in (Table 9).

Table 9: LSD test shows the mean differences and the P-value of the top and bottom microhardness among Filtek Z250 Universal Restorative groups.

Distance (mm)		Top		Bottom	
		Mean	p-value	Mean	p-value
0	2	3.125	0.653 (NS)	2.867	0.557 (NS)
	4	6.306	0.366 (NS)	6.989	0.156 (NS)
	6	7.529	0.282 (NS)	8.774	0.077 (NS)
	8	27.272	0.000 (HS)	25.799	0.000 (HS)
2	4	3.181	0.648 (NS)	4.122	0.400 (NS)
	6	4.404	0.527 (NS)	5.907	0.229 (NS)
	8	24.147	0.001 (HS)	22.932	0.000 (HS)
4	6	1.223	0.860 (NS)	1.785	0.714 (NS)
	8	20.966	0.004 (HS)	18.810	0.000 (HS)
6	8	19.743	0.006 (HS)	17.025	0.001 (HS)

The Bottom – Top Ratio

The Bottom-Top ratio of the three groups (Tetric EvoCeram Bulk Fill, SureFil SDR Flow and Filtek Z250 Universal Restorative) at different light tip distances are summarized in (Table 10).

Table 10: Bottom-Top ratio of different groups at different light tip distances.

Distance (mm)	Evobulk	SDR	Z250
0	0.76	0.87	0.84
2	0.74	0.83	0.83
4	0.65	0.82	0.82
6	0.58	0.79	0.81
8	0.47	0.72	0.80

Table shows that:

1. The bottom-top microhardness ratio of Tetric EvoCeram Bulk Fill group was less than the accepted value (0.8) at all light tip distances (0, 2, 4, 6, and 8mm).
2. The bottom-top microhardness ratio of SureFil SDR Flow group was more than the accepted value (0.8) at 0, 2, and 4 mm light tip distances and less than the accepted value (0.8) at 6 and 8 light tip distances.
3. The bottom-top microhardness raio of Filtek Z250 group was more than the accepted value (0.8) at all light tip distances (0, 2, 4, 6, and 8mm).

DISCUSSION

The results of this study revealed that top and bottom microhardness at 0 mm light tip distance for all groups show the highest mean value. This may be because the distance between the light tip and the resin composite can affect the light intensity that reaches the material and that 1 mm of air reduces light intensity by approximately 10% thus interferes in the polymerization depth and degree of conversion [17-19]. These findings come in agreement with the studies of Sobrinho and others [20], Caldas and others [21], Lindberg and others [22], Rakowski and others [23], Ergun and others [24] who stated that the resin composite polymerization and hardness depend greatly on the distance from the curing tip.

The results of this study show that the top microhardness more than the bottom microhardness at all light tip distances for all experimental groups with high significant differences. This may attributed to that at the top surface sufficient light energy reach the photoinitiator, thus starting the polymerization reaction. On the bottom surface the microhardness decreased because the resin composite has the property of dispersing the light of the light curing unit, thus when the light passes through the bulk of the composite, light intensity is reduced due to the light being scattered by filler particles and the resin matrix. It is found that 2 mm of composite are sufficient to reduce the light-inensity to 6% of its initial value [17, 20,25,26]. These findings come in agreement with the studies of Aguiar and others [27], Nogueira and others [28] who evaluate the influence of curing tip distance on the microhardness of the resin composite and they found that the top surface showed higher hardness values than the bottom surface. While, these findings disagree with the study of Miranda and others [19]. In which they did not observe a statistical difference between the top surface and the base for any of the composites tested, it is believed that the results obtained in this study are justified by the thickness of the specimen made (1mm).

Tetric EvoCeram Bulk Fill group

In this study, it clearly seen that, at 0 mm light tip distance there is significant difference in the top microhardness in comparison to 2 and 4 mm light tip distances and with high significant difference in comparison to 6 and 8 mm light tip distances. In addition, it can be seen that, at 0 mm light tip distance there is non-significant difference in the bottom microhardness in comparison to 2 mm light tip distance but with high significant difference in comparison to 4, 6, and 8 mm light tip distances. This study shows that with all light tip distances the bottom-top microhardness ratio was less than the accepted value (80%). This may be attributed to its high percentage of filler by weight which may increase the light attenuation as it pass through the bulk of the material due to light scattering, this will reduce the degree of polymerization of composite resins. Another possible explanation that, the lower ratio was affected by both the resin composite increment and the high distance from the resin composite to the light source [27]. As mentioned previously the light intensity reduced by approximately (6%) of its initial value when pass through the composite with 2 mm thickness, furthermore 1 mm of air reduces the light intensity by approximately (10%), thus decreasing the polymerization effectiveness. This may explain why the bottom to top microhardness ratio was less than the accepted value. These finding come in agreement with the studies of Thomé and others [10], Bagnato and others [16], they found that the nanofilled composite resin did not present satisfactory microhardness at the bottom due to great light attenuation. They found that this attenuation could be explained by the high percentage of filler.

An important finding of this study was that Tetric EvoCeram Bulk fill should not be polymerized with 4 mm depth in deep cavities even when the light curing tip distance was 0 mm. These finding come in agreement with study of Flury and others [29], who concluded that Tetric EvoCeram Bulk Fill showed no VHN value above 80% of VHN max.

SureFil SDR Flow group

From this study it can be seen that, at 0 mm light tip distance there is high significant difference in the top and bottom microhardness in comparison to 2, 4, 6 and 8 mm light tip distances. Moreover, it clearly seen that only at 0, 2, and 4 mm light tip distances the bottom-top microhardness ratio was more than the accepted value (80%). This could be attributed to that the depth of cure is directly related to filler particle size in dental composite resins, the larger particle composite had the greatest depth of cure, since it was less affected by light scattering [20]. In addition the presence of TEGDMA in the resin, which reduces the resin viscosity and increase the reactivity of the monomers [30]. Another possible explanation is due to that the photoactivation at 6 mm light tip distance led to a decrease of about 50% in the amount of irradiance reaching the material's surface. Coincidentally, for the 6 mm distance, the irradiance about half of the irradiance for the 0 mm distance, this light dispersion yielded to a loss of energy dose and probably promoted a lower camphorquinone excitation) and a polymer chain formation with lower crosslinks [31, 32, 33] Thus, there will be more space for solvent molecules to diffuse inside the polymer network, making the polymer more susceptible to the plasticization effect of solvent [34]. These findings come in agreement with the study of Miranda and others [19] who concluded that the curing tip distance affect the degree of conversion of composite resin only when cured to 6mm.

An important finding of this study was that SureFil SDR Flow should not be polymerized with 4 mm depth when the light curing tip distance was 6 mm or more.

Filtek Z250 Universal Restorative group

In this study, it clearly seen that, at 0 mm light tip distance there is non significant difference in the top microhardness in comparison to 2, 4, and 6 mm light tip distances but with high significant difference in comparison to 8 mm light tip distance. While at 2 mm light tip distance there is non significant difference in comparison to 4, and 6 mm light tip distances but with high significant difference in comparison to 8 mm light tip distance. In addition it can be seen that with all light tip distances the bottom-top microhardness ratio was equal or more than the accepted value (80%). This could be attributed to its high filler content and the thickness of the increment (2mm) which allows the polymerization light to reach the bottom surface better than the bulk increments (4mm) [28,35]. These findings come in agreement with Chung [36], Nogueira and others [28], Han and others [37] they found that increased concentration of filler particles improves hardness and depth of cure of light-cured composites.

An important finding of this study was that Filtek Z250 Universal Restorative could be polymerized with 2 mm depth even when the light curing tip distance was 8 mm. Therefore, the thickness of composite filling material is more important than the light curing tip distance.

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