

## Effect of Different Light-Curing Units on Microhardness of Different Bulk Fill Materials

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**Abstract: Objective:** To evaluate the effect of different curing units on the microhardness of three different bulk fill resin composites at different thicknesses. **Methods:** Three different bulk fill restorative materials (3M ESPE, Filtek Bulk Fill, St. Paul, MN, USA; Kerr, Sonic Fill, Orange, CA, USA; and DENTSPLY, SDR, DeTray GmbH, Germany) were tested in this study. Eighty discs of each tested material were made and divided into four subgroups (n=20) with different thicknesses (1, 2, 3 and 4 mm thicknesses). Each group was further subdivided into 2 classes (n=10); I. Cured with Elipar S10 (3M/ESPE), and II. Cured with Bluephase (Ivoclar Vivadent) both for 20 seconds continuous curing. The specimens were tested for microhardness using Vickers Microhardness Tester. Data were tabulated and statistically analyzed using three way ANOVA statistical analysis with P-value set  $\leq 0.05$ . **Results:** Sonic Fill had the statistically significant highest mean microhardness ( $128.4 \pm 4.4$ ). There was no statistically significant difference between Filtek Bulk Fill and SDR ( $120.9 \pm 4.5$  and  $120.4 \pm 3.8$  respectively); both showed the statistically significant lowest mean microhardness. There was no statistically significant difference between ultra thin and thin composite thickness subgroups; both showed the statistically significantly highest mean microhardness ( $125.2 \pm 4.6$  and  $124.5 \pm 4.5$  respectively). Medium thickness subgroup showed statistically significantly lower mean microhardness ( $123.5 \pm 4.5$ ). Thick composite thickness subgroup showed the statistically significantly lowest mean microhardness ( $119.7 \pm 6.7$ ). Class II samples (using Bluephase Ivoclar Vivadent curing unit) had statistically significant higher mean microhardness ( $126.5 \pm 5.0$ ) than class I samples (using Elipar S10 3M/ESPE curing unit) ( $120.0 \pm 3.9$ ) regardless of the other variables. **Conclusion:** Composite type, composite thickness, curing unit and the interaction between the three variables had a statistically significant effect on the mean surface microhardness. **Clinical Significance:** Selecting the appropriate light-curing unit with the appropriate increment thickness for the resin composite material used are important factors to determine the success of the restoration. Careful consideration of these factors and precise follow of the manufacturers' instructions is very important to ensure producing reliable and desired results.

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### 1. Introduction:

Nowadays, light-curing units come in variety that makes it sometimes confusing which one to use.<sup>1</sup> The use of light-curing unit with appropriate wavelength and time is important to ensure proper polymerization and thus performance of resin composite restorative materials.<sup>2-4</sup> Blue light with wavelength ranging between 400 and 525 nm is essential for the activation of Camphoroquinonepho to initiator within most resin composites.<sup>4-7</sup> The Light emitting diode (LED) provides a narrow spectrum of wavelength between 470 and 490 nm, which is close to the camphoroquinone excitation wavelength plus it will need less polymerizing energy.<sup>4,8</sup> LED produces blue light without requiring a filter, generate less heat and less degradation over time compared to halogen light curing units.<sup>9</sup>

Most of the previous studies compared the effect of using different curing light sources (LED, Argon laser, Quartz Tungsten Halogen, Xenon Plasma Arc...etc) on the polymerization of resin

composites.<sup>2,10-18</sup> It was claimed that providing similar energy densities will result in similar amount and depth of polymerization regardless of the light-curing mode.<sup>19-21</sup>

Evidence showed that bulk fill resin composite materials could be cured up to 4 mm thickness.<sup>22</sup> This requires the light radiation to pass through the full thickness of the material. Most research measured the microhardness of the surface at the other side of the light cure to ensure proper polymerization and thus hardening. The aim of this research is to find out if curing at deeper depth would affect the amount of light acting at the surface exposed directly to the light by measuring its microhardness. Also, to evaluate the effect of using the same type of light source (LED) but different unit make on the microhardness of different brands of bulk fill resin composites with different thicknesses.

### 2. Materials and Methods:

#### I. Preparation of the specimens:

Four specially fabricated split cylindrical Teflon molds were used for making the disc specimens of the three tested restorative materials. The first mold is of 2 mm internal diameter and 1 mm thickness, the second mold is of 2 mm internal diameter and 2 mm thickness, the third mold is of 2 mm internal diameter and 3 mm thickness while the fourth mold is of 2 mm internal diameter and 4 mm thickness.

### **II. Application of the restorative materials:**

Three different bulk fill resin composite restorative materials (3M ESPE, **Filtek Bulk Fill**, St. Paul, MN, USA; Kerr, **SonicFill**, Orange, CA, USA; and DENTSPLY, **SDR**, DeTray, GmbH, Germany) were tested in this study. The manufacturers and the detailed composition are presented in table (1). Eighty discs of each tested material were made.

Discs were fabricated by carefully inserting the tested restorative material using a nitride plated resin composite instrument (Aescolap, Germany) into a circumferential Teflon mold positioned onto a 0.051 mm thick transparent polyester film strip (Mylar, DuPont, Wilmington, Del., USA) over a glass slide. Then another 0.051 mm thick transparent polyester filmstrip was applied on top of the Teflon mold filled with the tested material. An additional glass slide was placed over the previously positioned polyester filmstrip, and a 1 kg weight was applied for one minute to extrude the excess material and to obtain a uniformly smooth specimen surface. Afterward the weight was removed and the tested restorative material was light cured using the assigned light-curing unit for 20 seconds through the polyester filmstrip. The output light intensity was continuously monitored with a radiometer (SDS Demetron, Orange, CA., USA) to ensure a constant value of 600 mW/cm<sup>2</sup>. A notch on the side to be examined for microhardness marked the top surface of the disc against which the load was applied. For the purpose of surface standardization, the side to be examined for microhardness of all specimens was wet ground with 600-grit silicon carbide abrasive papers for 10 seconds on a 300-rpm grinding machine (Buehler Metaserv, Buehler, Germany) following the protocol by El Seoud et al, 2009.<sup>23</sup>

### **III. Grouping of the specimens:**

Eighty discs of each tested material were made and subdivided into four subgroups (n=20) according to the discs' dimensions;

- 1) Ultrathin: 2mm diameter x1mm thick,
- 2) Thin: 2mm diameter x2 mm thick,
- 3) Medium: 2mm diameter x3mm thick, and
- 4) Thick: 2mm diameter x4 mm thick.

Each subgroup was further subdivided into 2 classes (n=10);

- I. Cured with Elipar S10 (3M/ESPE) for 20 seconds continuous curing, and

- II. Cured with Bluephase (IvoclarVivadent) for 20 seconds continuous curing.

### **IV. Microhardness Test:**

The specimens' surfaces that were assigned to evaluate the microhardness were examined using Digital Display Vickers Microhardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China) with a Vickers diamond indenter and a 20X objective lens. A load of 1000 g was applied to the surface of the specimens for 10 seconds. Three indentations were made on the surface of each specimen. These indentations were equally placed over a circle and not closer than 1 mm to the adjacent indentations or to the margin of the specimens. The diagonal lengths of indentations were measured by built-in scaled microscope and Vickers values were converted into microhardness values.

### **V. Statistical analysis**

Data were presented as mean and standard deviation (SD) values. Data were explored for normality by checking data distribution, histograms, calculating mean and median values and finally using Kolmogorov-Smirnov and Shapiro-Wilk tests of normality. Microhardness data showed parametric distribution; so three-way Analysis of Variance (ANOVA) was used in testing significance for the effect of composite type, composite thickness, curing unit and their interactions on mean microhardness. Bonferroni's post-hoc test was used for pair-wise comparison between the groups when ANOVA test is significant. The significance level was set at  $P \leq 0.05$ . Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows (IBM® Corporation, NY, USA).

### **3. Results:**

#### **Three-way ANOVA results:**

Three-way ANOVA results for the effect of different variables on the mean microhardness presented in table (2) showed that composite type, composite thickness, curing unit and the interaction between the three variables had a statistically significant effect on the mean surface microhardness. Since the interaction between the three variables is significant, so the variables (Composite type, thickness and curing unit) are dependent upon each other i.e. the effect of each variable is dependent upon the other variable. So the different levels within each variable are compared.

#### **Effect of composite type:**

The descriptive statistics and results of comparison between microhardness of the three composite types regardless of composite thickness or curing unit are presented in table (3). The results showed that Sonic Fill had the statistically significant highest mean microhardness. There was no

statistically significant difference between Filtek Bulk Fill and SDR; both showed the statistically significant lowest mean microhardness.

Table (4) showed the descriptive statistics and results of comparison between microhardness of the three different composite types with each composite thickness and curing unit. The results showed that with both curing units and with all composite thicknesses, Sonic Fill showed the statistically significantly highest mean microhardness. There was no statistically significant difference between Filtek Bulk Fill and SDR with all thicknesses with class I samples (using Elipar S10 3M/ESPE curing unit) and with the ultra thin and medium composite thicknesses (subgroups 1 & 3 respectively) with class II samples (using Ivoclar curing unit); both showed statistically significant lowest mean microhardness. While with thin and thick composite thicknesses (subgroups 2 & 4 respectively): Filtek Bulk Fill showed statistically significantly lower mean microhardness. SDR showed the statistically significantly lowest mean microhardness.

*Effect of composite thickness:*

The descriptive statistics and results of comparison between microhardness of the four composite thicknesses subgroups regardless of composite type or curing unit are presented in table (5). The results showed that there was no statistically significant difference between ultra thin and thin composite thickness subgroups; both showed the statistically significantly highest mean microhardness. Medium thickness subgroup showed statistically

significantly lower mean microhardness. Thick composite thickness subgroup showed the statistically significantly lowest mean microhardness.

Table (6) shows the Descriptive statistics and results of comparison between microhardness of different composite thicknesses with each composite type and curing unit. The results showed that ultra thin and thin thickness samples using any of the curing units with all the materials, except for Sonic fill class II samples (using Bluephase Ivoclar Vivadent curing unit), and medium thickness subgroups of class I samples (using Elipar S10 3M/ESPE curing unit) for Filtek bulk fill and Sonic fill, and class II samples (using Bluephase Ivoclar Vivadent curing unit) for SDR had the statistically significant highest mean microhardness values. Sonic fill class II samples (using Bluephase Ivoclar Vivadent curing unit) showed no statistically significant difference between the four composite thicknesses. The thick samples subgroup showed the statistically significant lowest mean microhardness values for with all materials and with both curing units.

*Effect of curing unit:*

The descriptive statistics and results of comparison between microhardness with the two curing units regardless of composite type and thickness are presented in table (7). The results showed that class II samples (using Bluephase Ivoclar Vivadent curing unit) had statistically significant higher mean microhardness than class I samples (using Elipar S10 3M/ESPE curing unit).

**Table (1): Manufacturers' names and Materials details and compositions:**

Material	Principal components	Manufacturer
Filtek Bulk Fill, Posterior Restorative	<p><b>The resin matrix:</b> AUDMA, UDMA, and 1, 12-dodecane-DMA.</p> <p><b>The filler:</b> Non-agglomerated/non-aggregated 20nm silica filler, a Non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, an aggregated zirconia/silica cluster filler (20nm silica and 4 to 11 nm zirconia particles), and a ytterbium trifluoride filler consisting of agglomerate 100 nm particles.</p>	3M ESPE, St. Paul, USA
SonicFill, nanohybrid composite restorative	<p><b>The resin matrix:</b> (1-methylethylidene) bis (4, 1-phenyleneoxy-2, 1-ethanedioxy-2, 1-ethanediyl) bismethacrylate. (1-methylethylidene) bis [4, 1-phenyleneoxy (2-hydroxy-3, 1-propanediyl)] bismethacrylate. 2, 2'-rthylenedioxydiethyl dimethacrylate.</p> <p><b>The filler:</b> Glass, oxide, and Silicon dioxide.</p>	Kerr Corporation, Orange, CA, USA
SDR, light curing composite	<p><b>The resin matrix:</b> SDR patented urethane di-methacrylate resin, Di-methacrylate resin, and Di-functional diluent.</p> <p><b>The filler:</b> Barium and Strontium alumino-fluoro-silicate glasses.</p>	DENTSPLY, DeTray GmbH, Germany

**Table (2): Three-way ANOVA results for the effect of different variables on the mean microhardness.**

Source of variation	Type III Sum of Squares	df	Mean Square	F-value	P-value
Composite type	1241.1	2	620.6	538.6	<0.001*
Composite thickness	389.7	3	129.9	112.7	<0.001*
Curing unit	977.7	1	977.7	848.5	<0.001*
Composite type x Thickness x Curing unit interaction	17.6	6	2.9	2.6	0.027*

df: degree of freedom = (n-1), \*: Significant at  $P \leq 0.05$

**Table (3): Descriptive statistics and results of comparison between microhardness of the three composite types regardless of other variables.**

Bulk Fill	Sonic Fill	SDR	P-value
Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
120.9 $\pm$ 4.5 b	128.4 $\pm$ 4.4 a	120.4 $\pm$ 3.8 b	<0.001*

\*: Significant at  $P \leq 0.05$ , Different superscripts in the same row are statistically significantly different.

**Table (4): Descriptive statistics and results of comparison between microhardness of composite types with each composite thickness and curing unit.**

Curing unit	Thickness	Bulk Fill	Sonic Fill	SDR	P-value
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
3M	Ultra thin	120.1 $\pm$ 1.6 b	125.6 $\pm$ 0.9 a	119.8 $\pm$ 1.5 b	<0.001*
	Thin	119.9 $\pm$ 1.4 b	124.3 $\pm$ 1.0 a	120.1 $\pm$ 1.7 b	<0.001*
	Medium	119.6 $\pm$ 1.4 b	124.2 $\pm$ 1.0 a	118.6 $\pm$ 0.7 b	<0.001*
	Thick	113.1 $\pm$ 1.2 b	122.8 $\pm$ 0.8 a	114.0 $\pm$ 1.3 b	<0.001*
Ivoclar	Ultra thin	127.2 $\pm$ 0.9 b	132.8 $\pm$ 1.2 a	125.8 $\pm$ 0.7 b	<0.001*
	Thin	126.1 $\pm$ 0.6 b	132.7 $\pm$ 0.7 a	123.8 $\pm$ 1.1 c	<0.001*
	Medium	123.9 $\pm$ 1.1 b	132.2 $\pm$ 1.0 a	123.3 $\pm$ 0.7 b	<0.001*
	Thick	120.0 $\pm$ 0.3 b	132.5 $\pm$ 0.7 a	117.8 $\pm$ 1.0 c	<0.001*

\*: Significant at  $P \leq 0.05$ , Different superscripts in the same row are statistically significantly different.

**Table (5): Descriptive statistics and results of comparison between microhardness of the four composite thicknesses regardless of other variables.**

Ultra thin	Thin	Medium	Thick	P-value
Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
125.2 $\pm$ 4.6 a	124.5 $\pm$ 4.5 a	123.5 $\pm$ 4.5 b	119.7 $\pm$ 6.7 c	<0.001*

\*: Significant at  $P \leq 0.05$ , Different superscripts in the same row are statistically significantly different.

**Table (6): Descriptive statistics and results of comparison between microhardness of composite thicknesses with each composite type and curing unit.**

Curing unit	Type	Ultra thin	Thin	Medium	Thick	P-value
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	
3M	Bulk Fill	120.1 $\pm$ 1.6 a	119.9 $\pm$ 1.4 a	119.6 $\pm$ 1.4 a	113.1 $\pm$ 1.2 b	<0.001*
	Sonic Fill	125.6 $\pm$ 0.9 a	124.3 $\pm$ 1.0 a	124.2 $\pm$ 1.0 a	122.8 $\pm$ 0.8 b	0.006*
	SDR	119.8 $\pm$ 1.5 a	120.1 $\pm$ 1.7 a	118.6 $\pm$ 0.7 b	114.0 $\pm$ 1.3 c	<0.001*
Ivoclar	Bulk Fill	127.2 $\pm$ 0.9 a	126.1 $\pm$ 0.6 a	123.9 $\pm$ 1.1 b	120.0 $\pm$ 0.3 c	<0.001*
	Sonic Fill	132.8 $\pm$ 1.2	132.7 $\pm$ 0.7	132.2 $\pm$ 1.0	132.5 $\pm$ 0.7	0.852
	SDR	125.8 $\pm$ 0.7 a	123.8 $\pm$ 1.1 a	123.3 $\pm$ 0.7 a	117.8 $\pm$ 1.0 b	<0.001*

\*: Significant at  $P \leq 0.05$ , Different superscripts in the same row are statistically significantly different.

The descriptive statistics and results of comparison between microhardness of the two curing units with each composite type and thickness are presented in table (8). The mean and standard deviation values (error bars) of microhardness in the different groups are presented by Bar chart in figure (1). Class II

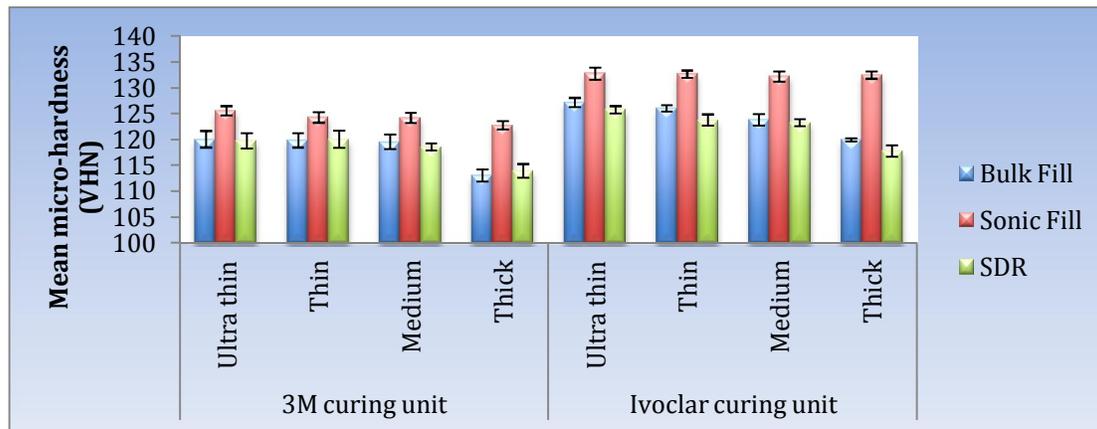
samples (cured using BluephaseIvoclarVivadent curing unit) for all the three bulk-fill resin composite types showed statistically significant higher surface microhardness values for all the thickness subgroups compared to class I samples (cured using Elipar S10 3M/ESPE curing unit).

**Table (7): Descriptive statistics and results of comparison between microhardness with the two curing units regardless of other variables.**

3M	Ivoclar	P-value
Mean $\pm$ SD	Mean $\pm$ SD	
120.0 $\pm$ 3.9	126.5 $\pm$ 5.0	<0.001*

\*: Significant at  $P \leq 0.05$ **Table (8): Descriptive statistics and results of comparison between micro-hardness of the two curing units with each composite type and thickness.**

Composite type	Thickness	3M	Ivoclar	P-value
		Mean $\pm$ SD	Mean $\pm$ SD	
Bulk Fill	Ultra thin	120.1 $\pm$ 1.6 b	127.2 $\pm$ 0.9 b	<0.001*
	Thin	119.9 $\pm$ 1.4 b	126.1 $\pm$ 0.6 b	<0.001*
	Medium	119.6 $\pm$ 1.4 b	123.9 $\pm$ 1.1 b	<0.001*
	Thick	113.1 $\pm$ 1.2 b	120.0 $\pm$ 0.3 b	<0.001*
Sonic Fill	Ultra thin	125.6 $\pm$ 0.9 a	132.8 $\pm$ 1.2 a	<0.001*
	Thin	124.3 $\pm$ 1.0 a	132.7 $\pm$ 0.7 a	<0.001*
	Medium	124.2 $\pm$ 1.0 a	132.2 $\pm$ 1.0 a	<0.001*
	Thick	122.8 $\pm$ 0.8 a	132.5 $\pm$ 0.7 a	<0.001*
SDR	Ultra thin	119.8 $\pm$ 1.5 b	125.8 $\pm$ 0.7 b	<0.001*
	Thin	120.1 $\pm$ 1.7 b	123.8 $\pm$ 1.1 c	<0.001*
	Medium	118.6 $\pm$ 0.7 b	123.3 $\pm$ 0.7 b	<0.001*
	Thick	114.0 $\pm$ 1.3 b	117.8 $\pm$ 1.0 c	<0.001*

\*: Significant at  $P \leq 0.05$ **Figure (1): Bar chart representing mean and standard deviation values (error bars) of micro-hardness in the different groups.**

#### 4. Discussion:

The above results showed that the resin composite type, curing unit, and the bulk thickness are factors that affect the surface microhardness value of the cured resin composite material. It showed that regardless of the curing unit used or curing thickness, Sonic fill bulk fill resin composite had the highest surface microhardness results. This might be due to compositional differences in the filler type and amount. In agreement with our study, Czasch P and Ilie N found that there was a statistically significant difference in the mechanical properties and degree of cure between two flowable bulk fill materials (SDR

and Venus bulk fill) regardless of irradiation times and materials thicknesses used.<sup>24</sup> They used flowable bulk fill materials that require a capping layer by the manufacturers. Another study that supports our finding in having the type of material as a significant factor affecting microhardness was done by **Correr et al** and found that regardless of the light source or energy density, the surface microhardness of Z250 resin composite specimens was statistically significantly higher than Esthet-X resin composite specimens.<sup>19</sup>

In our study, both curing units are LED type and both were monitored with a radiometer to ensure a

constant value of 600 mW/cm<sup>2</sup>. Yet, the curing unit type used significantly affected the surface microhardness results regardless of the bulk fill resin composite type or thicknesses. Previous studies compared the effect of using different light sources or light curing techniques on the degree of cure or surface microhardness and not using the same light source and technique but different light curing unit manufacturer.<sup>2,10-18</sup> If the microhardness values were related to the degree of polymerization then our results are not in agreement with studies that found that regardless of the light-curing mode, providing similar energy densities would result in similar degree of conversion and depth of polymerization.<sup>19-</sup>  
<sup>21</sup>Factors related to the curing unit used other than the type of light source, light density, curing mode or curing time can affect the degree of cure of the resin composite material. Since both curing units used in our study provided similar energy output and both used on the same materials, significantly better microhardness results of specimens cured using Bluephase Ivoclar Vivadent curing unit might be explained by the different light characteristics of Bluephase Ivoclar Vivadent than other LEDs including Elipar S10 curing unit. Unlike other LED curing units, which have limited light spectrum compared to halogen lights, Bluephase is a polywave LED curing unit with halogen-like broadband spectrum (385-515 nm). This gives Bluephase the advantage of curing materials, which do not exclusively have camphoroquinone as a photoinitiator.<sup>25</sup>In agreement with our study, a study by Correr et al found that surface microhardness results were statistically significantly different using different light sources and that increasing energy density resulted in higher surface microhardness results with LED and xenon plasma arc (PAC) but not with QTH light.<sup>19</sup>

Our results comparing the microhardness of composite thicknesses showed that there was no significant difference between the ultrathin and thin thicknesses with any resin composite type or curing unit. This means that thickness of 1-2 mm will have sufficient polymerization for all the used bulk fill resin composite with both light curing units. The results indicated that increasing the thickness beyond 2 mm could affect the degree of polymerization and thus surface microhardness of the material. Using the proper curing time, unit and technique is crucial to ensure proper setting of the bulk fill resin composite material. Factors related to reflectance and absorbance of light through the thickness of the material could result in the variation we got for the surface microhardness at the medium and thick subgroups thicknesses. This is in correspondence to the study by Price et al who found that with increasing specimens thickness, there will be an exponential decrease in

light energy transmitted for all the specimens from 7 different resin composites cured using 2 different light intensities.<sup>26</sup> Flury et al found that increasing the thickness of resin composite materials will lead to decrease in the microhardness results of conventional resin composites but not for the bulk fill resin composites.<sup>27</sup>The study by Czasch et al found that for the two bulk fill resin composites tested, there was a highly reliable depth of cure to at least 6 mm depth and they recommended curing in 4 mm bulk for 20 seconds.<sup>24</sup>

### Conclusion:

The bulk fill resin composite type, thickness and curing unit type are all factors that influence the degree of polymerization and the surface microhardness of the material. Sonic fill material had the highest mean microhardness compared to the other bulk fill resin composites. Ultrathin and thin samples (1 and 2 mm respectively) had the highest mean microhardness values compared to the medium and thick samples (3 and 4 mm respectively). Higher mean microhardness results were found when using Bluephase compared to Elipar S10 curing unit. Careful consideration of these factors and precise following of the manufacturers' instructions is very important to ensure producing reliable and desired results.

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