ORIGINAL RESEARCH

Comparison of Four Different Light-curing Units and Evaluation of the Depth of Cure and Microhardness of Nanohybrid Composite Resin

Megha Gugnani[1], Mamta Singla[2], Mandeep S Grewal[3], Anshul Arora[4], Gaurav Setya[5], Ayush Jain[6]

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Abstract

Aim: The current *in vitro* study compared four different light-curing units and evaluated the depth of cure and microhardness of nanohybrid composite resin.

Materials and methods: Ninety-six composite specimens were obtained using polyurethane molds with 5 mm diameter and 2, 4, and 6 mm depth. Each specimen was light-cured using four different light-curing units (Bluephase N, iLED, SmartLite Focus, and Elipar DeepCure-L) for 20 seconds. The Vickers microhardness (VK) of the surface was determined by a microhardness indenter with a load of 200 gm applied for 15 seconds. The hardness ratio = VK of the bottom surface/VK of the top surface was calculated and compared. Depth of cure using a scraping method described in the International Organization for Standardization (ISO) standard for resin-based composites was performed, and mean was calculated and compared.

Results: Data were analyzed using analysis of variance (ANOVA) test. Significant differences were found in hardness ratio and depth of cure (DOC) of samples cured by abovementioned light sources.

Conclusion: Bluephase N reaches the minimum value indicated in literature (0.8) and depth of cure of 1.5 as compared to other light-curing units.

Clinical significance: Clinicians need to follow the manufacturer's instructions for each light and to be cured accordingly to obtain a properly cured composite resin.

Keywords: Depth of cure, Hardness ratio, Light-emitting diode, Nanohybrid composite, Vickers hardness.

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Introduction

The resin-based composites have become more popular in the world of dentistry, mainly because of their esthetic quality and good physical properties.[1] Adequate polymerization is considered a crucial factor in maintaining a good clinical outcome.[2,3] There is a converse relationship between the polymerization of the core of the restoration and the material's chemical composition, whereas the hardness of composite resins is directly related to the polymerization depending on polymerization time, distance of polymerization light, irradiation power, thickness of the increment inserted into the cavity, and distance of the tip of the light-curing unit to the material to be activated.[1] The intensity of light is also related to the distance of the tip of the light to the material and the tip diameter of the light. Dental curing light, which is used for polymerization of light cure resin-based composite is present with different wavelengths. Different generations of curing lights are divided on the basis of wavelengths like the quartz-tungsten-halogen (QTH), light-emitting diode (LED), plasma arc lights, and argon ion lasers. The latest light-curing unit is the LED. The peak wavelength of LEDs is in the ideal range of 455–480 nm for activating the most popular photoinitiator, camphor quinone.[4] The QTH curing units have many shortcomings over the latest LED curing units as it is bulkier, lacking blue light and stable output, and have a working time of 50–100 hours if used according to the manufacturer's instructions as compared to the LED lights which can work for thousands of hours if used carefully.[5] The third-generation LED lights have irradiance of 1000–3000 mW/cm² having violet as well as blue diodes without any other filters with a wide range of power application methods, including units with bimodal or payWave spectra.[4]

[1]Department of Conservative Dentistry and Endodontics, Maharishi Markandeshwar College of Dental Sciences and Research, Maharishi Markandeshwar (Deemed to be University), Ambala, Haryana, India

[2,3]Department of Conservative Dentistry and Endodontics, SGT Dental College Hospital & Research Institute, SGT University, Gurugram, Haryana, India

[4]Department of Conservative Dentistry and Endodontics, ITS Dental College, Ghaziabad, Uttar Pradesh, India

[5]Private Practitioner, New Delhi, India

[6]Department of Orthopedic Surgery, MM Institute of Medical Sciences & Research, Maharishi Markandeshwar (Deemed to be University), Ambala, Haryana, India

Corresponding Author: Megha Gugnani, Department of Conservative Dentistry and Endodontics, Maharishi Markandeshwar College of Dental Sciences and Research, Maharishi Markandeshwar (Deemed to be University), Ambala, Haryana, India, Phone: +91 9690513615, e-mail: drmeghagugnani@gmail.com

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According to the manufacturer's instructions, Bluephase N curing light unit (Ivoclar Vivadent, Schaan, Lichtenstein) can cure composite up to a depth of 2 mm when cured for 20 seconds, reaching the adequate depth of cure according to International Society of Automation (ISA) standards.

According to the manufacturer's instructions, iLED curing light (Woodpecker™) can cure composite up to a depth of 2 mm when cured for 1–3 seconds, reaching the adequate depth of cure according to ISA standards.

SmartLite Focus curing light (Dentsply Sirona) has a wavelength of 470 nm and intensity of 1000 mW/cm^2. It is efficient in curing up to 8 mm from the tip and can cure up to 4 mm, and has a depth of cure of 2 mm according to ISA standards.[6]

Elipar DeepCure-L curing light (3M ESPE) has light irradiance of 1470 mW/cm^2 and wavelength of 430–480 nm. It can cure 4–4.5 mm thick composite resin with 10 seconds of curing time having the tip centrally placed.[7]

Composite resins can be classified according to filler features, such as type, distribution, or average particle size as follows: macrofill, microfill, hybrid, and nanofill. With the introduction of nanotechnology in dentistry, a new class of resin composite nanocomposites, the nanofilled and nanohybrid composite resin provide a material having esthetics of a microfill and the strength of a hybrid with high initial polishing ability combined with superior polish and gloss retention, excellent handling and wear similar to enamel.[8–10]

Filtek Z350 XT (3M ESPE) is a universal restorative visible light-activated composite designed for use in anterior and posterior restorations. It is available in different shades. The body shades are slightly more opaque, less translucent than the enamel shades to enable use in single-shade restorations. As the shade increases, the curing depth decreases and the hardness decreases.[11] Measuring the degree of conversion is one of the major fundamentals of checking the mechanical properties of the material. Different testing techniques, either directly like the depth of cure testing techniques or indirectly like the scrapping test, can be used to measure the degree of monomer conversion of resin composites.[2] Vickers hardness value is one of the most important measurements to compare the degree of conversion of restorative materials.[8] The scraping test of the depth of cure has also been found to be beneficial in checking the degree of conversion.[10]

The current *in vitro* study focused on curing a nanohybrid composite resin with four different light-curing units at three different depths. The VK and depth of cure after curing were evaluated and compared. The comparative evaluation of the effect of Bluephase N, iLED, SmartLite Focus, and Elipar DeepCure-L on the depth of cure has not been reported in the past.

Materials and Methods

A nanohybrid composite resin with A2D shade (Filtek Z350 XT, 3M ESPE, St Paul, Minnesota, USA) was used in this study as the test material. The curing light sources used in the study are mentioned in Table 1.

Table 1: List of LED curing lights

LED light	*Manufacturer*
Bluephase N	Ivoclar Vivadent
iLED	Woodpecker
SmartLite Focus	Dentsply
Elipar DeepCure-L	3M ESPE

Composite specimens were grouped according to the four different LED curing lights mentioned above having 24 samples each and then subgrouped according to the different heights of the specimen (2, 4, and 6 mm), having eight samples each.

Preparation of Resin-based Composite Specimens

Ninety-six cylindrical shaped nanohybrid composite specimens measuring 5 mm in diameter and 2, 4, and 6 mm in thickness were prepared using three polyurethane molds. The mold was placed on a glass plate of 1 mm thickness with a Mylar strip over it. The composite resin was then packed in a single increment using plastic filling instrument and then covered with another Mylar strip along with a glass plate followed by the application of finger pressure to extrude the excess, to achieve good adaptation of composite in the mold and to guarantee the superficial smoothness. The glass plate was then removed, leaving the Mylar strip in its position. All composite specimens were polymerized with four different LED curing lights for 20 seconds from the top surface only. The samples were stored in dark for 24 hours in a dry environment, at 37°C.

VK Testing

The microhardness was checked at the bottom and top surfaces. The microhardness of the uncured/bottom surface was measured after scrapping off the uncured composite using a microhardness tester having a diamond indenter with a force of 200 gm for 15 seconds along the length of the cured samples on the flat side perpendicular to the surface. There was one indentation point on each side of the sample. Measurement of the microhardness indent of each side was taken on horizontal and vertical axis, and then the average was calculated. The hardness ratio = VK of the bottom surface/VK of the top surface was calculated and compared.

Depth of Cure Measurement

For the evaluation of depth of cure, the composite samples were removed from the mold, and then the soft uncured part was scraped off from the uncured surface. The remaining cured composite sample was measured in height from all sides, and then the value was divided by two.[12]

Statistical Analysis

The statistical software, Statistical Package for the Social Sciences (SPSS version 21.0) was used to calculate descriptive data, and one-way and two-way ANOVA test with *post hoc* Tukey test and the Shapiro-Wilk W test was used for the analysis of the data.

Results

Analysis of the data revealed significant ($p < 0.05$) differences among the samples cured by the light sources in terms of Vickers hardness and depth of cure.

The mean Vickers hardness ratio after curing with four different light-curing units for 20 seconds each at 2, 4, and 6 mm soon after scrapping away the uncured resin is shown in Table 2 and Figure 1. The mean Vickers hardness values of top and bottom surfaces are shown in Table 3.

Group A (Bluephase N) had the maximum mean VK ratio for 2, 4, and 6 mm, that is, greater than or equal to 0.80, followed by group B (iLED), group C (SmartLite Focus), and the least was seen in group D (Elipar DeepCure-L). Group A at all levels and all the other groups

Table 2: Ratio statistics for uncured microhardness/cured microhardness

		2 mm		*4 mm*		*6 mm*	
Group		*Mean*	*Std. deviation*	*Mean*	*Std. deviation*	*Mean*	*Std. deviation*
A	Bluephase N (Ivoclar Vivadent)	0.922	0.018	0.883	0.013	0.816	0.014
B	iLED (Woodpecker)	0.883	0.023	0.698	0.003	0.699	0.001
C	SmartLite Focus (Dentsply)	0.891	0.012	0.695	0.010	0.694	0.005
D	Elipar DeepCure-L (3M ESPE)	0.913	0.015	0.697	0.006	0.600	0.001
	p-value	0.001, SIG		0.001, SIG		0.001, SIG	
	Post hoc	A, D > B, C		A > B, C, D		A > B, C, D	

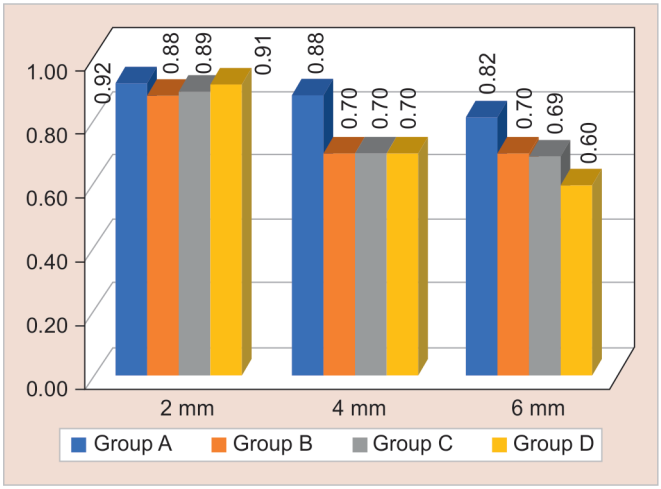

Fig. 1: The comparison of ratio microhardness uncured/cured among four different curing lights at 2, 4, and 6 mm

at 2 mm met the criteria that the depth of cure is said when the hardness value of the top or the cured composite surface is 80–90% greater than or equal to the hardness value of the bottom or the uncured composite surface.[9]

Depth of Cure

Two-way ANOVA test for checking depth of cure using scrapping method has shown that for 2 mm, all groups had equal value and at 4 mm group A (Bluephase N) had maximum value followed by group C (SmartLite Focus), group D (Elipar DeepCure-L), and group B (iLED). Whereas at 6 mm group A (Bluephase N) had maximum value followed by group C (SmartLite Focus), group D (Elipar DeepCure-L), and the least of group B (iLED) (Table 4 and Fig. 2).

Discussion

This study was conducted to evaluate and compare the depth of cure and microhardness of a nanohybrid composite resin after curing using four different light-curing units at three different depths. The light-curing units used in this study have never been used together in literature. The results of this study have rejected the null hypothesis of all four curing units having same curing effect.

All four LED curing light units used are of third generation having irradiance of 1000–3000 mW/cm^2.

Bluephase N curing light (Ivoclar Vivadent, Schaan, Lichtenstein) has a wavelength of 385–515 nm and irradiance of 1200 mW/cm^2. According to Miletic and Santini, the depth of cure did not increase after curing but rather persisted over the 48-hour period. Santini et al. found the use of polywave LEDs including Bluephase G2, which improved the degree of conversion and Knoop hardness of materials.[13,14] This result was in accordance with the result as Bluephase N had the best highest microhardness values.

iLED curing light (Woodpecker™) has a wavelength of 420–480 nm with light intensity of 1000–2500 mW/cm^2. Al-Khatieeb et al. concluded that the shear bond strength of metal orthodontic brackets cured for 1 second and 3 seconds using iLED curing light were higher than halogen one, which were cured for 40 seconds.[15]

SmartLite Focus LED curing light (Dentsply Sirona) has a wavelength of 470 nm and intensity of 1000 mW/cm^2 and can cure up to 4 mm, and has a depth of cure of 2 mm according to ISA standards.[6]

Elipar DeepCure-L curing light (3M ESPE) claims to cure 4–4.5 mm thick composite resin with 10 seconds curing time having tip centrally placed. Nassar et al. concluded that Elipar DeepCure-L is capable of curing bulk-fill composites to achieve restorations with predictable properties and long service life.[7]

The composite used in this study is nanohybrid composite Filtek Z350 XT by 3M. Rizzante et al. concluded that Filtek Z350 XT and Filtek Z350 XT flowable have lower depth of cure when compared with bulk-fill resin composites, and all bulk-fill resin composites presented depth of cure higher than 4.5 mm and similar or lower polymerization shrinkage than conventional resin composites.[11] Rosa et al. concluded that Grandio and Filtek Z350 XT both had the highest diametral tensile strength values, and Filtek Z350 XT and Esthet-X had the highest flexural strength. Very few studies have been conducted on the VK of Filtek Z350 XT therefore, this study was conducted using Filtek Z350 XT.[16]

The polymerization of the composite resin depends on the wavelength and intensity of the light. Irradiance decreases as we go from center to the sides of the light guide or tip.[5] With the increase in the tip diameter and the distance between the tip and the material, the intensity of light decreases. All these factors, along with the radiant power of liquid crystal display decide the success and longevity of resin composite restorations.[7]

Degree of conversion can be checked by either calculating the surface hardness or through the depth of cure of the composite resin. Surface microhardness can be checked using a microindenter on the cured and the uncured surface and then calculating the ratio of both. The depth of cure can be checked using the scrapping method according to the ISO standardization. Depth of cure is important to check the adequate polymerization of the composite sample.[12]

According to the results of this study, group A (Bluephase N) had the maximum mean VK ratio for 2, 4, and 6 mm followed by group B (iLED), group C (SmartLite Focus), and the least was seen in group D (Elipar DeepCure-L). This result is contraindicated with the hypothesis because of variation in height and by using four different light-curing units and as each light has different photopolymerization reaction with the composite particles.

Table 3: Comparison of microhardness: cured and uncured among four different curing lights at different depths

		Cured microhardness		*Uncured microhardness*	
		Mean	*SD*	*Mean*	*SD*
2 mm					
Bluephase N (Ivoclar Vivadent)	8	78.650	2.1554	72.500	1.6716
iLED (Woodpecker)	8	77.713	5.2613	68.650	5.6391
SmartLite Focus (Dentsply)	8	78.075	3.0677	69.588	2.7663
Elipar DeepCure-L (3M ESPE)	8	82.888	4.1354	75.663	4.1102
p-value			0.041, SIG D > B		0.005, SIG D > B, C
4 mm					
Bluephase N (Ivoclar Vivadent)	8	77.075	2.1413	68.038	1.9595
iLED (Woodpecker)	8	67.400	3.5805	47.063	2.4389
SmartLite Focus (Dentsply)	8	75.225	3.6966	52.275	2.7753
Elipar DeepCure-L (3M ESPE)	8	80.038	4.9871	55.813	3.4803
p-value			0.001, SIG D > A, C, B		0.001, SIG A > D, C > B
6 mm					
Bluephase N (Ivoclar Vivadent)	8	70.688	3.1760	57.663	2.9325
iLED (Woodpecker)	8	71.000	2.5174	49.663	1.7848
SmartLite Focus (Dentsply)	8	71.325	4.0896	49.500	2.6849
Elipar DeepCure-L (3M ESPE)	8	85.988	5.0980	51.563	3.1341
p-value			0.001, SIG D > C, B, A		0.001, SIG A > D, B, C

Table 4: Comparison of four different light-curing units on depth of cure using scrapping method

	Group	*Depth of curing*	*N*	*Mean*	*Std. deviation*
Group A	Bluephase N (Ivoclar Vivadent)	2 mm	8	1.0000	0.00000
		4 mm	8	1.5000	0.00000
		6 mm	8	1.5000	0.00000
Group B	iLED (Woodpecker)	2 mm	8	1.0000	0.00000
		4 mm	8	1.0000	0.00000
		6 mm	8	1.0000	0.00000
Group C	SmartLite Focus (Dentsply)	2 mm	8	1.0000	0.00000
		4 mm	8	1.1875	0.25877
		6 mm	8	1.1250	0.23146
Group D	Elipar DeepCure-L (3M ESPE)	2 mm	8	1.0000	0.00000
		4 mm	8	1.0000	0.00000
		6 mm	8	1.1042	0.20743

On comparing the VK values of the nanohybrid composite of the cured surface, at 2 mm group D (Elipar DeepCure-L) had maximum values, followed by group A (Bluephase N), group C (SmartLite Focus), and group B (iLED). At 4 mm, group D had maximum values followed by group A, group C, and group B. At 6 mm somewhat similar results were seen with maximum values of group D followed by group C, group B, and group A, and for uncured surface, it was observed that for 2 mm group D (Elipar DeepCure-L) had maximum but for 4 and 6 mm group A (Bluephase N) had maximum values as compared to other groups.

According to Pires et al., the top cured surface has adequate hardness and is less hardness of independent on light intensity than the bottom surface.[17,18] It stated that the top surface utilizes

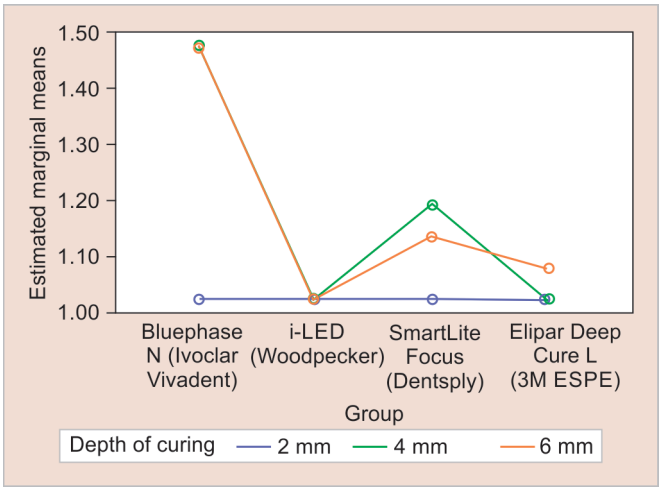

Fig. 2: Line graph showing depth of cure values of four different light-curing units using scrapping method

maximum energy of the lights, therefore, even low-intensity lights can cure the composite almost equal to the extent of high intensity curing lights. Therefore, the hardness values and the hardness ratio combined go in accordance with the above statement.

The result showed a significant difference between the values of cured and uncured microhardness for 2, 4, and 6 mm for all four groups. For a given irradiation time, it can be anticipated that the VK of the composite decreases as the thickness of resin cured increases.

According to ISO #4049, 1.5 mm is the value after scrapping off the uncured composite sample. This ISO scraping test technique was used as a mode of checking the depth of cure as it requires minimal instrumentation and is easy to perform anywhere. Only the better half, that is, the hard composite is used to check the depth of cure to avoid underpolymerization.[19]

Two-way ANOVA test for checking depth of cure using scrapping method, it was found that for 2 mm, all groups had equal value and at 4 and 6 mm group A (Bluephase N) had maximum value followed by group C (SmartLite Focus), group D (Elipar DeepCure-L), and group B (iLED).

According to a study conducted by Moore et al., darker shades had less depth of cure and microhardness values as compared to the lighter shades of the same composite.[20] Therefore, it can be concluded that use of different light-curing units gives different depths of cure and different VK values depending on many factors like the height of the increments being cured, the type of composite being used, the diameter of the light cure, the collimation of the light being used, and the shade of the composite.

This data suggests that the manufacturers need to provide detailed information on the number of composite increments to be used and the time of the curing cycle for the bottom layer to be cured adequately and to achieve proper depth of cure because the microhardness decreases as the height of the composite increases.[18] It was also observed that smaller increments and longer exposure time are recommended for darker shades.[21] The details should be mentioned according to the material type along with its shade so that the dentist can implement a proper placement procedure that will help adequate curing of a restoration. The curing of new light-curing units should be checked for the composites of a variety of brands at different depths.

Clinical Significance

The results of this study should be carefully used clinically as they may vary according to the composite type and shade used with the brand of curing light with varying wavelength and curing time. Curing light used should be of sufficient energy density or intensity which can very well cure the entire height of the increment of composite.[18]

Limitations

In this study, the composite is placed in the form of flat disks, whereas, in clinical situations, the composite is inserted in tooth cavities having different morphologies and complex anatomies, which may influence the depth of irradiation of light resulting in different depths of cure of the composite.

Conclusion

It can be concluded that Bluephase N had maximum VK ratio and depth of cure as compared to other curing lights that had hardness ratio less than 0.80–0.90 at 4 and 6 mm. Therefore, Bluephase N can be used clinically.

Further research is required to determine which light-curing unit is best suited to clinical scenarios where the composite placement is according to variable morphology and depth of the tooth.

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