Original Article

Comparative Depth of Cure Among Two Light-Cured Core Build-Up Composites By Surface Vickers Hardness

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Abstract

Objective: Depth of cure of composite material is restricted and it depends on many parameters such as thickness. The aim of this in-vitro study was to evaluate the depth of cure of two light-cured core build-up composites (Quixfil and Photocore) in different thicknesses, when cured for 60 seconds.

Materials and Methods: The Vickers microhardness measurements were made for each side of the top irradiated surfaces of 1,2,3,4,5,6,7 and 8-mm-thick cylindrical blocks of two core build-up light-cured composites (Quixfil and Photocore) and a micro hybrid composite (Z250) as the control group. For each thickness a bottom to top Vickers Hardness Number (VHN) ratio was determined and a value of at least 80% was used to indicate the acceptable depth of curing. The results were analyzed with two way ANOVA and Tukey HSD test. P value<0.05 was considered significant.

Results A two way ANOVA indicated that both the depth of cure and VHN were significantly influenced by composite type (P< 0.001) and thickness (P< 0.001). The bottom to top VHN ratio reflecting the relative curing degree showed acceptable curing at a depth of 5 mm for Quixfil and Photocore; however, it was 3 mm for Z250. The surface micro hardness of Photocore was significantly higher than the other materials in all thicknesses.

Conclusion: Although both two composites can be bulk cured, their curing depths were lower than that was expected. Curing depth is a property which is material specific and decreases with thickness (P < 0.001).

Key Words: Microhardness; Depth of Cure; Polymerization; Core Build-Up Composite

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INTRODUCTION

Light curing units and light-cured resin composites have revolutionized restorative dentistry [1]. Different factors can influence curing degree such as filler particle size, filler loading, polymerization initiator concentration [2], monomer type, amount of monomer, silane coupling agent, the shade and translucency of the material, intensity and distance of the incident light, wavelength of the light, irradiation-

times [3], design and size of the light guide and increment thickness[4].

An inadequate curing degree affects the chemical and physical properties of the resin composite, such as water absorption, discoloration, wear resistance, strength [2], elution of the possible irritant, toxicity, hardness, marginal breakdown, bond between the tooth, adhesive and the restoration [4].

In order to minimize these undesired effects, a composite resin should be cured to a high degree and to an appropriate depth as well [5]. Because light intensity decreases as the light travels through composite resin [2], for proper polymerization a typical 2mm thickness composite restoration requires a power density of at least 400mW/cm^2 with 20 seconds irradiation time for halogen based light curing units [6]. Therefore, the most commonly recommended thickness of resin composite placed with incremental layer technique is 2mm in clinical practice [3, 6]. One factor known to influence the depth of cure is exposure time. As expected, 40-second exposures led to significantly higher depths of cure than 20-second exposures for all curing units [7].

However, Ceballos showed that exposure time had no influence on the microhardness values for 0.5 to 2.5 mm depths. At higher depths, irradiation for 40 seconds produced greater microhardness values, but a further increase in the exposure time from 40 to 60 seconds did not result in significant microhardness improvement [8].

However the total energy (intensity of curing unit × exposure time) is important in the depth of cure,it has some disadvantages such as temperature rise and pulpal effects because of the heat [7].

It has been shown for some products that a threefold difference in intensity only had a 15% difference in the depth of cure [6].

So some manufacturers introduced core build-up composites and claimed that they can be used in high thickness with the bulk-curing technique because they have a high depth of cure. Some examples are 9 mm in 20 seconds for Photocore and 4.4 mm in 10 seconds for Quixfil. Polydorou evaluates the curing depth of two translucent composites; namely, Quixfil and Amament compared to a hybrid composite (Tetric ceram).

Table 1. Characteristics of the Investigated Material

Composite	Z250	Quixfil	Photocore
Manufacturer	3MESPE, St, Paul, MN, USA	Dentsply Detrey GmbH, Kontanz ,Germany	Kuraray Medical, Okayama, Japan
Color	A2	Universal	Universal
Main Composition	UDMA Bis-EMA Bis-GMA TEGDMA Camphorquinone	Bisphenol-A-dimethacrylate, UDMA, TEGDMA Trimethylopropane Trimethacryalte, butane-1,2,3,4-tetracarboxylic acid, bis-2-hydrohyethyl methacrylate, photoinitator and accelerator: dimethylaminobenzoic acid ethyl ester Camphorquinone	Silanted glass Powder Silanted barium Glass powder TEGDMA Bis GMA dl-Camphorquinone
Filler Particle Size(µm)	0.01-3.5	1-10	6
Volume of Filler (%)	60	66	65
Weight of Filler (%)	82	86	83

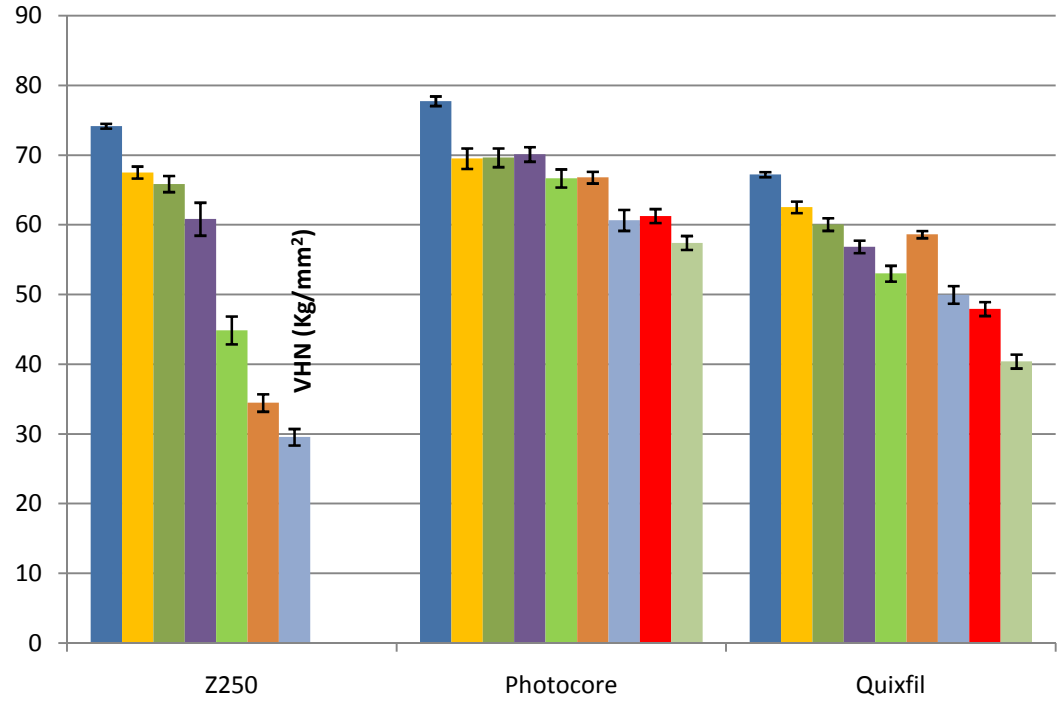

Fig. 1. VHN in Kg/mm^2 for each composite in each thickness. The error bars represent the standard deviations

The curing depth of Quixfil was 4.5 mm with a halogen based curing unite and 5.5 mm for an LED curing unite [2]. Curing depth is evaluated by two direct and indirect methods. One of the indirect methods is microhardness which is the most popular method [4]. For a specimen constructed from composite, in different thicknesses the bottom to top hardness ratios ranging from 0.80-0.90 have been used as criteria for the adequate degree of conversion at a specific sample thickness [9, 10]. The aim of his study was to evaluate the possibility of adequate curing-depth in bulk-curing of two translucent core build-up composites other than incremental technique, which are said to have a high depth of cure. The depth of cure was measured on the basis of Vickers hardness of the top and bottom surface.

MATERIALS AND METHODS

The materials used in this study, with their respective compositions according to the manufacturers are given in Table 1.

Two core build-up composites (Photocore, Kurary medical,
Okayama, Japan) and (Quixfil, Denstsply Detrey GubH, kontaz, Germany) and a micro hy brid composite (Z250 , 3M ESPE Dental product, St. Paul MN, USA) were selected.

As a halogen light source for all procedures a Coltolux 75 light curing unit (coltene / Whaledent, Mahawash, Nj, USA) with 800-820 mW/cm^2 output and 420-510 nm wavelength was used. Before each curing, the power density was checked with a halogen-based radiometer (Demetron 100, SDS/Kerr, USA).

Eight polytetrafluoroethylene hollow cylindrical molds, 8mm inner diameter and 10mm outer diameter with different heights of 1,2,3,4,5,6,7 and 8 mm were provided.

To prepare each specimen, the mold was placed on a clear glass slide, the resin composite was placed in the mold and then covered with a mylar matrix. Finally, a 1-millimeter-thick glass-slide was placed on the top of it immediately and was held by finger pressure

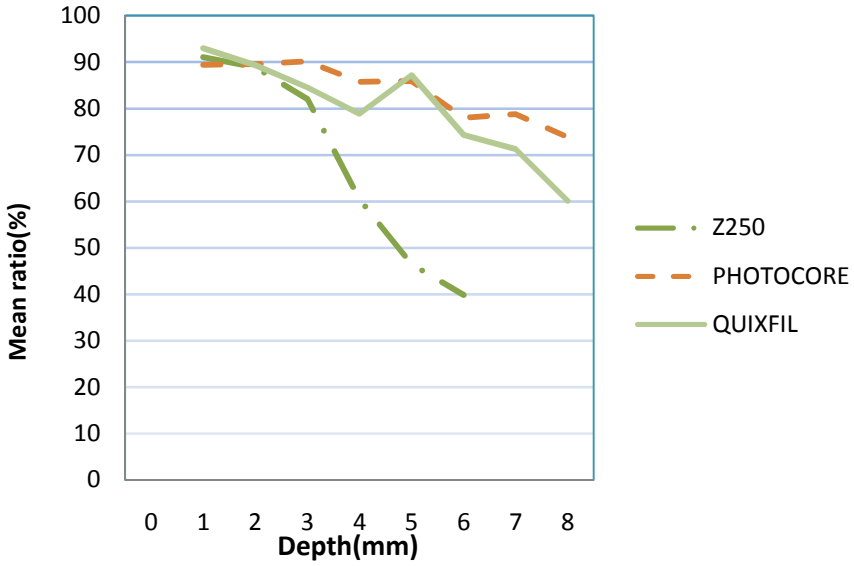

Fig 2. B/T VHN ratio in 3 composites as a function of depth

to exude excess materials. Only the top side of the specimen was irradiated with visible light polymerization unit for 60 seconds. The head of the visible light cured unit was in touch with the glass-slide during exposure.

In this way, we prepared 144 specimens of three selected resin composites for each composite type (n=48) and there were 8 subgroups according to their mold height (n=6 for each subgroup). The samples were removed from the mold and the bottom surfaces were marked to distinguish them from top surfaces.

Samples were stored at room temperature in light-proof containers for 24 hours. Then the bottom and top Vickers hardness were determined using a Vickers hardness tester (Beahler LTD, USA) with 100 gr load application for 15 seconds. For each sample, three VHN readings were recorded for the irradiated top and non irradiated bottom surfaces. Then for each thickness, the mean value and corresponding standard deviation of the VHN were measured. Besides, a bottom to top VH percentage was determined and a value of 80% was used to indicate acceptable curing.

We conducted statistical analysis of data using two way analysis of variance (ANOVA) to evaluate the hardness of the composite in different thicknesses. Tukey HSD was used as a post HOC test for multiple comparisons between the groups.

RESULT

The mean value and corresponding standard deviation of VHN as a function of depth is summarized in Table 2. Kolmogorov-Smirnov test determined that data distribution in the top and bottom surfaces of the samples were normal. Then a two way ANOVA studied the effect of the composite type and thickness on VHN. It showed that there was a significant interaction between composites and thicknesses ($P<0.001$) (Fig. 1). So Tukey test was conducted for multiple comparisons between the groups.

The mean VHN in the top surface of composites had significant difference. A Tukey test demonstrated that the VHN of the top surface (thickness= 0) of the materials decreased in the following order:

Photocore > Z250> Quixfil
Moreover, for 1 and 2 mm thicknesses, the bottom VHN of Quixfil was significantly lower than the two other composites.
In 3-mm thickness only the VHN for Photocore was significantly higher than the two other composites, but in other thicknesses (4 and 5 mm) there were significant differences between all three composites in the following order:
Photocore > Quixfil > Z_{250}
The satisfactory depth of cure for Z_{250} was up to 3mm and up to 5mm for the two other composites (Fig. 2).
None of them had an adequate curing depth in 6, 7 and 8 mm thicknesses; therefore, statistical analysis was not performed for these depths.

DISCUSSION

The degree of polymerization plays an important role in physical and mechanical properties of composite materials [4].
There are direct and indirect methods for investigating the depth of cure. Infrared spectroscopy and laser ramon are direct methods and microhardness, scratching and visual inspection are some of the indirect methods [4]. Direct methods are complex, expensive and time consuming; however, microhardness testing appears to be the most popular method because the other indirect methods tend to overestimate the curing depth. Surface microhardness (Vickers or Knoop) has been shown to be an indicator of the degree of conversion and correlates well with the infrared spectroscopy [4].The bottom to top hardness ratios ranging from 0.80-0.90 have been used as criteria for the adequate degree of conversion at a specific sample thickness [9, 10]. It means that the bottom to top surface microhardness ratio of 80% or more is adequate curing. In microhardness tests (Vickers, Koop), magnitude of load has a significant effect on microhardness results. It should be in the range of 1grf to 1kgf and the most common is 100-500 grf. The indenter with higher load penetrates deeper into the composite, reaches the harder layer and therefore measures a greater hardness [11]. Because the optimum cure and therefore hardness is often reached slightly below the surface layer where the light transmission is high, no oxygen is present and a significant heat build-up occurs [11].In our study, the load was 100 grf and the dwell time was 15 seconds.

Table 2. Mean Value and Corresponding Standard Deviations VHN as a Function of Thickness in Materials Used in This Study (*Undetectable)

	Z250		PHOTOCORE		QUIXFIL	
0	74.163	(0.3481)	77.742	(0.6924)	67.208	(0.3712)
1	67.522	(0.8584)	69.506	(1.4598)	62.522	(0.8276)
2	65.867	(1.1594)	69.639	(1.3488)	60.056	(0.8999)
3	60.822	(2.3635)	70.111	(1.0498)	56.856	(0.9045)
4	44.883	(1.9934)	66.661	(1.2997)	53.017	(1.1343)
5	34.467	(1.2444)	66.789	(0.8439)	58.617	(0.5130)
6	29.556	(1.1899)	60.661	(1.5051)	49.972	(1.2755)
7		*	61.278	(0.6210)	47.939	(0.7089)
8		*	57.417	(1.1947)	40.417	(1.0325)

The result of Yoldaz study showed that a dwell time of 15 seconds could be accepted as an actual time of load application limit for the dental composite [12]. Curing light irradiance, exposure time and composite are variables significantly affecting hardness and curing depth [13], although ceballos showed an exposure time higher than 40 seconds is not effective [8].In the present study although manufacturers recommended different exposure times for adequate curing depth, Quixfil 20 seconds, Photocore 10 seconds and Z250 20 seconds, in our study the exposure time was 60 seconds in order to have maximum curing and the same experimental conditions.

Yazici determined that the bottom Knoop hardness number (KNH) of a composite cured with LED curing units is greater than halogen-based curing units [14]. Ceballos demonsterated that the depth of cure was not influenced by curing lights [8]. Our curing light was a halogen based unit. In all samples, the distance between the light guide tip and the composite was 1 mm, in line with Krishna study which said the distance can decrease the curing depth [15]. In the present study, the hardness decreased with thickness and the acceptable depth of cure for Z250 was up to 3 mm, but for Photocore and Quixfil it was up to 5mm.

Several researches showed that the depth of cure decreased with the increase in thickness, which is congruent with our study [8, 10].

Polydoraou showed a 4.4 mm depth of cure for Quixfil using KHN [2].

In another research conducted by Quixfil manufacturer, Quixfil had a 4.4 mm satisfactory depth of cure and Z250 had an up to 2.6 mm depth of cure. They used the scraping method which overestimates the results. Ceballos showed a curing depth of 3 mm for Z250 using VHN [8].

In literature review, we did not find any research regarding the depth of cure for Photocore. Owing to similarity in experimental conditions, the high depth of curing in Quixfil and Photocore can be because of the difference in organic matrix (monomer type, monomer concentration and photoinitiator concentration), greater filler size and translucency than Z250. As Polydorou and Ceballos demonstrated the effect of these factors in their study [2, 8].

Light scattering in composite with a smaller particle size can cause a lower depth of cure [3, 10], especially those similar in size to the wavelength of emitted light [10, 5]. So Quixfil and Photocore with a higher filler size (1-10 µ and 6µ, respectively) have a higher depth of cure than Z250 with 0.01 -3.5 µ filler particle size. The relationship between monomer conversion and inorganic filler loading is inversely proportional, as light transmission decreases with the increased filler loading [16]. But Boucschlicher showed B/T VHN ratios is independent of filler loading and size. He used fabricated composites with the same shade, resin matrix and photoinitiator, but a different filler loading and size [10]. In our study, Quixfil and Photocore with the approximately same filler loading with Z250 have a greater curing depth than Z250. Quixfil contains dimethylaminobenzoic acid ethyl ester as an accelerator besides the photo initiator camphorquinone [2]. This may also be the reason for its different performance in comparison to Z250.

Translucency is another factor in the depth of curing [2, 16]. Glass particles have an important role in light transmission [8]. Photocore contains silanated glass powder and silanated barium glass powder which are not found in the two other composites. Glass and it translucency can cause a high depth of curing and hardhness for the composite [2, 16]

Photocore had a higher hardness in all thicknesses than the two other composites; maybe, the glass fillers and translucency are the reason. We achieved a lower curing depth for both composites than that expected.

It is suggested to evaluate the curing depth of these composites with LED curing lights probably leading to a better curing depth. In addition, experiments are necessary to investigate the shrinkage behavior of these materials using bulk curing until their clinical advantages can be confirmed.

CONCLUSION

Curing depth and microhardness were inversely related with thickness. Besides, the curing depth is a property which is material specific.
So for being on the safe side, it is recommended to apply composite in the layering technique with 2mm thickness in each layer.

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