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INFLUENCE OF HIGH IRRADIANCE LIGHT CURING ON THE MICROMECHANICAL PROPERTIES OF BULK FILL RESIN-BASED COMPOSITES

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ABSTRACT

Objective: Proficient polymerization of resin composites is essential to obtain long term clinical success and has a great significance attaining improved mechanical properties. The purpose of this study was to investigate the effects of two curing light intensities on the mechanical properties (Vickers microhardness) of bulk-fill resin-based composites. **Materials and methods:** An in vitro investigation was carried out, where a total of 40 cylinders were fabricated utilizing Tetric N-Ceram bulk fill (TNC) and SDR Plus bulk fill flowable (SDR) (n=20). Each material group, specimens were divided into two subgroups according to the light intensities; full mode and turbo mode (n=10). Resin composite specimens were prepared in clinically realistic layer thicknesses (4 mm). The specimens were irradiated from only one side for the suggested time for both curing modes. Vickers hardness number (VHN) was measured on the top and bottom surfaces of resin composite specimens 24h after light-curing. Bottom/top ratio [Vickers hardness ratio (VHR)] was calculated as a measure of depth-dependent during effectiveness. **Results:** The results revealed that the irradiation of TNC with either full mode or turbo mode showed no statistical significant difference in VHN values either on top or bottom surfaces and VHR. Meanwhile, SDR irradiated with full mode showed higher VHN values compared to samples irradiated with turbo mode on both top and bottom surfaces and VHR. **Conclusion**: Rapid and high curing light intensity could be used for polymerizing TNC restorations. TNC reported higher hardness values when compared with SDR employing both curing modes.

KEYWORDS: Bulk fill resin based composite, curing modes, Vickers microhardness

INTRODUCTION

Of late, adhesive dentistry is following unceasing trend toward simplification of the restorative procedures, achieved through development of materials and techniques. Such dynamic process was highlighted by the evolution of bulk-fill resin composites, universal adhesives, and high-intensity light-curing units. These advancements allowed a decline in the risk of iatrogenic errors [(1)].

Worth to mention that, direct composite restorations in the dental practice are applied routinely owing to their outstanding esthetic characteristics and long survival rate. It is well documented that the resin composite is composed mainly of organic matrix, inorganic fillers, activator-initiator system in addition to other constituents [(2)].

During light polymerization of resin composites, the high radiant exposure levels are compulsory to achieve satisfactory mechanical properties together

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with biocompatibility. Such high radiant exposure is driven by material-related factors and light curing unit related factors [3].

The material related factors comprises; photoinitiator type, material thickness, material shade and fillers type. The most commonly used photoinitiator in resin composites is camphorquinone (CQ). However, as a result of its shortcomings, modern photoinitiators were introduced such as; phenyl-propanedione (PPD), diphenyl (2,4,6-trimethylbenzoyl) phosphine oxide (TPO) and ivocerin [4,5].

So as to achieve appropriate polymerization of the light cured composites, compatibility between the photoinitiator and wavelength of the light delivered by the curing unit is mandatory. In the dental market, numerous light curing units were introduced namely Quartz-tungsten-halogen (QTH), light emitting diodes (LED), plasma arc (PAC) and argon laser units [6].

The light curing units differ in their light output, produced wavelength and subsequently their compatibility with the photoinitiators of resin composites [7,8].

With the evolution of the LED curing units, the light output increased up to 3000mW/cm^2. This high light output mode could be identified as turbo, high power or plasma emulation mode. Such mode diminished the curing time to merely 3 seconds [9].

LED curing units have three generations; the first one provides monowave-low output units; the second generation units have monowave – high output, while the third generation units are polywave units [9].

As the chair- side time saving is critical from a clinical standpoint for both operator and patient, the increased light output from the first to second generation of LED curing units led to a decrease in the curing time [10].

A further approach to reduce the chair time was recognized by introduction of bulk-fill resin composite, which was considered advantageous for filling the cavity up to 5 mm in one step with satisfactory surface properties, reduced marginal leakage[11] depth of curing and polymerization shrinkage compared to the conventional resin composites [12].

It is worth to mention that surface microhardness reflects not only the material's resistance to wear and abrasion but for a given resin-based material, microhardness also has been shown to be an indirect measure of the degree of conversion of the polymer [13].

Hence, the purpose of this study was to assess the efficiency of applying two curing light intensities on the depth of cure and the surface hardness of two bulk fill resin composite restorations.

MATERIALS AND METHOD

Two bulk fill composite resin restorations were used in the study namely; Tetric N-Ceram bulk fill (TNC) and SDR Plus bulk fill flowable (SDR). The samples of resin composite were polymerized with a LED light curing unit (Premium plus light cure C02-S, Premium Plus UK, England) with two light intensities; full mode (1200 mW/cm^2 for 20 seconds) and turbo mode (2500 mW/cm^2 for 3 seconds).

Specimens grouping

A total of 40 cylinders (8 mm in diameter x 4mm in length) were fabricated, 20 specimens from each composite resin material. Half of the specimens were polymerized with full mode (FM) for 20 seconds and the other half with turbo mode for (TM) 3 seconds.

Specimens preparation

Specially fabricated split Teflon mold (with internal diameters 8 mm in diameter and 4 mm in length) was used to fabricate the specimens. The specimens were irradiated from only one side which is called the top side and the other is called the bottom side. The composite resin specimens were stored in a dry dark place at 37°C for 24 hours, to complete the post-cure reaction [1].

TABLE (1) Materials used in the study, composition, manufacturer and lot number.

Brand	Composition	Manufacturer
TNC	**Organic matrix** (21%): Bis-GMA (bisphenol A-glycidyl dimethacrylate), Bis-EMA (bisphenol A-ethoxylated methacrylate) and UDMA (urethane dimethacrylate). **Fillers:** barium aluminium silicate glass with two different mean particle sizes, filler content approximately 61% (vol.) and 17% polymer fillers or "Isofillers" **Initiator:** camphorquinone (CQ) (plus an acyl phosphine oxide, together with a recently patented initiator Ivocerin	Ivoclar vivadent AG, 9494 Schaan/ Liechtenstein
SDR	**The resin matrix:** contains proprietary modified UDMA; TEGDMA; polymerizable dimethacrylate resin; polymerizable trimethacrylate resin; (CQ) photoinitiator; ethyl-4 (dimethylamino) benzoate photoaccelerator; butylated hydroxy toluene (BHT). **The filler:** contains silanated barium-alumino-fluoro-borosilicate glass; silanated strontium alumino-fluoro-silicate glass; surface treated fume silicas; ytterbium fluoride; synthetic inorganic iron oxide pigments, and titanium dioxide.	Dentsply Caulk, USA

Vickers microhardness test

Immediately after completion of post-cure reaction, each of the 40 specimens was fixed in a holder with the test surface (top and bottom) perpendicular to the diamond indenter tip of a VMH tester (Buehler Micromet 2, Lake Bluff, IL, USA). Surface microhardness was determined by the application of (100 gm load (HV 0.1). time = 10 seconds). Five indentations were made at random positions around the center of each surface of the sample. The same machine was used to view and measure the indentation at 40× magnification. Utilizing the built-in scale and the manufacturer's conversion table, Vickers values were obtained and converted to microhardness values (Vickers hardness number, VHN). Mean values for five indentations were calculated for all tested specimens. The Vickers hardness ratio (VHR) for each specimen was calculated from equation: bottom VHN/ top VHN x 100.

Statistical analysis

Statistical analysis was performed with IBM® SPSS® Statistics Version 25 for Windows. The mean and standard deviation values were calculated for each group. Normality test was performed using Kolmogorov-Smirnov test and revealed normal distribution between values of each group. Homogeneity test was performed using Levene's test and revealed homogenous distribution between all variables. Therefore, 2 independent sample T test was performed between the variables (with significance level was set at $P \leq 0.05$) to reveal the statistical significant difference.

RESULTS

Top and bottom surfaces hardness

The TNC-FM and TNC-TM subgroups showed no statistical significant difference in hardness values on both top or bottom surfaces ($p > 0.05$). On the other hand, SDR-FM showed higher surface hardness values compared to SDR-TM specimens on both top and bottom surfaces. Moreover, TNC-FM reported higher hardness values in comparison to SDR-FM at the top and bottom surfaces. Furthermore, TNC-TM recorded higher hardness values in comparison to SDR-TM on both top and bottom surfaces

The Vickers hardness ratio (VHR)

There was no statistical significant difference in VHR between the specimens of TNC-FM and TNC-TM. On the other hand, SDR-FM specimens showed statistical significant higher values of VHR when compared to SDR-TM specimens.

TABLE (2): Vickers hardness values (MPa ± SD) of top and bottom and hardness ratio (% ± SD) of tested materials.

	VHN (Top Surface)			VHN (Bottom Surface)			VHR		
	FM	TM	P- value	FM	TM	P- value	FM	TM	P- value
TNC	42.52 ± 3.63	43.88 ± 4.2	0.474	36.68 ± 2.94	33.70 ± 8.37	0.338	84.55 ± 6.64	77.69 ± 13.4	0.187
SDR	29.60 ± 0.66	25.23 ± 3.26	0.004 *	21.63 ± 0.6	16.07 ± 2.66	0.000 *	73.13 ± 2.96	63.77 ± 6.92	0.008 *
P-value	0.000 *	0.000 *		0.000 *	0.000 *				

* Indicates the mean difference is statistically significant at the 0.05 level.

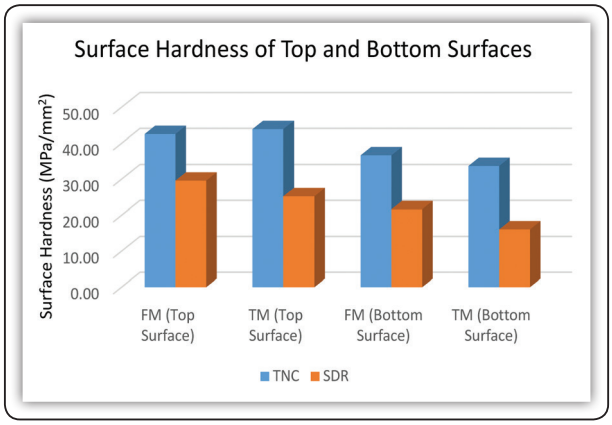

FIG (1) Surface Hardness Values of top and bottom surfaces for both tested materials.

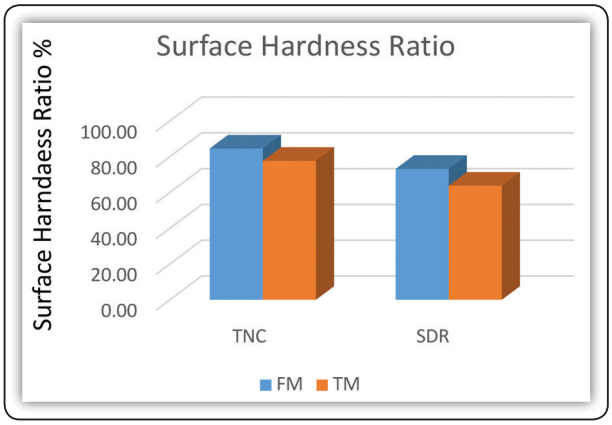

FIG (2): Surface Hardness Ratio for both tested materials

DISCUSSION

The introduction of bulk fill resin composites offers reliable means to overcome some limitations of the conventional resin composites resulting from the layering technique used for its placement. These drawbacks include extended working time and weakening of the restoration resulting from failure of bond between the increments due to the risk of air bubbles incorporation or contamination between layers [14]. It has been stated that it is impossible to entirely eliminate the incidence of voids between resin composite increments [11]. The bulk fill resin composite showed increased depth of curing as a result of its higher translucency. Based on that, its increment may reach up to 5 mm with curing parameters 550 mW/cm^2 for 20 seconds [15].

Worth mentioning that, Vickers hardness test gives consistent and reliable results and is described as being easy and suitable for brittle materials. Surface hardness is affected by several factors such as; amount, distribution, size and, to less extent, the density of the fillers, the type and cross linking of the matrix and photoinitiator materials [16,17].

With respect to the results of the current study, higher Vickers hardness top and bottom surfaces values were reported with TNC when compared with SDR with both curing modes. This could be explained by the higher fillers percent of the former resin composite (75-77% by weight) compared to the later (70.5% by weight) as claimed by the manufacturers. Haugen et al., reported that surface hardness is related to the percent of fillers incorporated within the resin composite material [17].

Another explanation concerning the lower Vickers hardness values with SDR could be the monomer chemistry of its matrix which contains a patent polymer entitled by manufacture "polymerization modulator" having high flexibility. That is why the manufacture recommends using SDR as a liner for Class I and Class II and to be overlayed with a posterior resin composite.

The results of the current investigation were coping and in a line with other authors who reported lower hardness values of SDR compared to TNC composites [18,19].

In contradiction with our results, Sarma and Nagar reported that SDR recorded greater hardness values than TNC. This could be justified by utilizing conventional light curing unit which is more compatible with the photoinitiator of SDR (camphorquinone) rather than photoinitiators of TNC (camphorquinone and acyl phosphine oxide together with ivocerin) [20].

In the present study, top and bottom surface hardness was measured to evaluate the depth of cure of the tested materials. Calculating bottom over top micro-hardness values provides an indirect indication about the curing depth of resin composites and subsequently the curing efficiency [21].

The high light transmission through bulk fill composites is a result of modification of the material by several methods such as the use of brighter shades, larger filler size, decrease in the fillers' percent and matching the refractive indices between fillers and matrix. Increasing the filler size results in decreasing the filler-matrix interface due to lower surface area of the large particles compared to smaller particles. It is documented that at the filler-matrix interface, light scattering takes place. Thus, the light scattering is declined by using larger filler size with subsequent increase in the light transmission [17,22,23].

The results of the present study showed no statistical significant difference between VHR between TNC-FM and TNC-TM, while SDR-FM reported higher VHR when compared to SDR-TM.

Worth mentioning that, ivocerin the photoinitiator employed in TNC has a higher extinction coefficient and requires less light energy to be excited to produce radicals compared to camphorquinone the photoinitiator of SDR [4,5]. What is more, the ivocerin produces two radicals while camphorquinone produces only one radical [4, 24].

Therefore, the short application time of the TM produces sufficient radicals in TNC due to presence of ivocerin. While in SDR, it appears that the camphorquinone photoinitiator requires more curing time to produce adequate radicals required for proper polymerization of the matrix. Rosha et al., reported no significant difference in specimens of bulk fill composites cured with two curing modes at 955 mW/cm^2 and 2244 mW/cm^2 [25].

CONCLUSION

Within the limitations of this study, the following can be concluded:

High-intensity rapid light-curing showed a complex material-dependent effect on the micromechanical properties and the depth of cure. Turbo mode could be convenient for polymerizing TNC, conversely with respect to SDR the full mode would be recommended.

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