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Original Article

INFLUENCE OF POLYMERIZATION FACTORS AND VARYING SHADE COMPOSITIONS OF BULK FILL RESIN-BASED NANOHYBRID COMPOSITES ON UNDER-SURFACE TEMPERATURE

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ABSTRACT

Objective: This study aimed to evaluate the influence of polymerization factors and varying shade compositions of bulk-fill resin-based nanohybrid composites on under-surface temperature.

Methods: A total of 120 bulk-fill resin-based nanohybrid composite specimens (n=10) consisting of IVW (whiter), IVB (medium), and IVA (darker) shades were inserted in one bulk into a polyvinyl siloxane mold with a diameter of 5 mm and a thickness of 4 mm, divided into 2 subgroups of irradiation times (20 s and 30 s) and 2 subgroups of light curing sources (LED and QTH). When the specimen was polymerized, the under-surface temperature was measured with a K-type digital thermocouple. Data analyzed using Three-Way ANOVA and Tukey HSD Post Hoc tests.

Results: It showed significantly different QTHs that generated lower under-surface temperature than LEDs (P<0.05); whiter shade generated the highest temperature among all. However, there was no significant difference between 20 s and 30 s irradiation time (P>0.05).

Conclusion: It was concluded that the under-surface temperature generated by polymerization factors and varying shade compositions of bulk fill resin-based nanohybrid composites in this study was still acceptable and safe for dental pulp tissue.

Keywords: Under-surface temperature, Bulk fill resin-based nanohybrid composite, Polymerization factors, Shade

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INTRODUCTION

Bulk fill resin-based nanohybrid dental composites are composed of a complex mixture of matrices, nanohybrid fillers, coupling agents, photoinitiators, and optical modifiers that may be polymerized in bulk to a depth of cure of up to 4-5 mm without needing the use of incremental techniques, thus have excellent mechanical properties [1-4]. In order to improve mechanical properties, more nanohybrid reinforcement fillers are added to the resin-based dental composites than the matrices, which are consisted of a group of crosslinked dimethacrylate monomers, including BisGMA (bisphenol A-diglycidylether dimethacrylate), UDMA (urethane dimethacrylate), TEGDMA (triethylene glycol dimethacrylate), and BisEMA (ethoxylated bisphenol A glycol dimethacrylate) [5-9]. The optical properties of resin-based composites can be improved by adding optical modifiers of metal oxide pigment to adjust the visual shade so that it more closely resembles dentin and dental enamel [9]. The more metal oxides added, the whiter the resin-based composite produced [10].

Resin-based composites require light to initiate the polymerization process. Light curing source and irradiation time are important factors that influence polymerization. Light-emitting diodes (LED) and quartz tungsten halogen (QTH) are common light-curing sources used in dentistry. QTH has a lower ability to convert electrical energy into light and requires a filter to limit the heat energy transferred to tooth structures, while an LED curing unit that does not require a filter to produce blue light and has a higher ability to produce light [10, 11]. According to the light intensity or irradiation strength of the curing unit, the light impacts the polymerization of the restorative materials. The light curing source can produce an increase in the temperature of the resin composites due to light absorption and exothermic processes. This high temperature can increase heat conductivity and diffusivity may cause the possibility to raise heat inside a tooth pulp chamber. When the temperature rises above 42.5 °C, pulp tissue may irreversible damage [12-18].

Likewise, the irradiation times, particularly in large cavities, influence the temperature increase at the undersurface of the resin composite during the polymerization process. Changes in temperatures might generate stress on the pulp. When exposed to external stimuli, pulp, which is vascularized tooth tissue that contains the main regulatory system for the heat distribution process, is particularly susceptible to temperature changes [12-16]. Shade variations in resin-based composites manufactured to match the color of patients' teeth are influenced by the differing compositions that cause light to be absorbed, reflected, dispersed, and transmitted [15]. Shade, according to previous studies, can affect the under-surface temperature. In the studies that have been carried out on conventional resin composites, the under-surface temperature after irradiation with a light curing unit was 47.8 °C–55.0 °C, which exceeded the threshold value for dental pulp tissue [17].

The main objective of this study was to find out the under-surface temperature of bulk fill resin-based nanohybrid composites that were safe for the health of dental pulp tissues with different light-curing sources, irradiation times, and shades were used.

MATERIALS AND METHODS

Preparing master cast

The master cast was made from polyvinyl siloxane with putty consistency (Perfit, Huge, China). A baseplate wax was made with a thickness of 4 mm, and perforated with a diameter of 5 mm, then implanted into the cuvette with dental stone. The cuvette will be placed in boiling water for 20 min. After cooling, the cuvette was opened and rinsed with hot water to remove the wax residue; then, a negative cast will be formed. Polyvinyl siloxane dough was made by mixing the catalyst and base by hand for 30 s, then placing it into a cast-negative mold and pressing it until the excess elastomeric dough comes out. After hardening, the polyvinyl siloxane was removed from the negative cast and trimmed.

Preparing polyvinyl siloxane holder

Polyvinyl siloxane dough by mixing catalyst and base manually by hand for 30 seconds. The dough was made into blocks and shaped according to the part of the master cast, thermocouple cable, or light curing unit, then fixed and waited for it to harden.

Preparing bulk-fill resin composite specimens

A total of 120 (n=10) bulk fill resin-based nanohybrid composites (Tetric

N Ceram® bulk fill, Ivoclar Vivadent, Liechtenstein) consisting of IVW (whiter), IVB (medium), and IVA (darker) shades were inserted in one bulk into the polyvinyl siloxane mold, divided into 2 subgroups of irradiation times (20 s and 30 s) and 2 subgroups of light sources (LED (LED. D, Woodpecker, China), with light intensity of 1000 mW/cm2, and QTH (Litex 680A, Dentamerica, USA) with light intensity of 700 mW/cm2). After inserting the material, it was pressed with a glass slab for 1 minute to produce a specimen that was not hollow and had a flat surface. Then the excess bulk fill resin composite was trimmed and the top surface in contact with the light curing unit was coated with a celluloid strip. When the specimen was polymerized using light curing unit in one irradiation, the under-surface temperature of the bulk fill resin composite was measured with a K-type digital thermocouple (Krisbow® KW06-278, China) with the cable of the thermocouple was connected to the under-surface of the bulk fill resin composite as it is assumed to be the surface in contact with the underlying tooth tissue, and then temperature that appeared on the digital thermocouple monitor was recorded.

Composition of bulk-fill resin-based nanohybrid composites investigated

The monomer matrices were composed of dimethacrylates (19–21% weight). The total content of inorganic fillers was 75–77% weight or 53-55% volume, consisting of barium glass, prepolymer, ytterbium trifluoride and mixed oxides. Additives, catalysts, stabilizers and pigments were additional contents (<1.0% weight). The particle size of the fillers used was between 0.04 and 3 µm, and the mean size was 0.6 µm.

Statistical analysis

By using Statistical Package for the Social Sciences (SPSS) version 20 (SPSS, IBM, Chicago, IL, USA), all data obtained were analyzed with three-way ANOVA with a 95% significance level.

Table 1: Mean and SD of under-surface temperature of bulk-fill resin-based composites

Light curing source	Irradiation time (s)	Shade	N	Under-surface temperature mean±SD (°C)
LED	20	IVW (whiter)	10	40.32±1.29
		IVB (medium)	10	38.57±1.37
		IVA (dark)	10	38.32±1.19
	30	IVW (whiter)	10	40.55±1.40
		IVB (medium)	10	38.62±1.25
		IVA (dark)	10	38.37±1.11
QTH	20	IVW (whiter)	10	39.65±1.34
		IVB (medium)	10	37.77±0.66
		IVA (dark)	10	37.52±0.65
	30	IVW (whiter)	10	40.10±1.66
		IVB (medium)	10	38.34±0.80
		IVA (dark)	10	38.09±0.67

RESULTS

The under-surface temperature mean and standard deviation (SD) of bulk fill resin-based nanohybrid composites were presented in table 1. There was a statistically significant difference between LED and QTH light sources (P<0.05), but there was no statistically significant difference between irradiation time of 20 s and 30 s (P≥0.05) (table 2). In table 2, it was also shown that there was no interaction between light source, irradiation time, and shade (P≥0.05). It showed that there was a statistically significant shade difference between IVW and IVB, as well as between IVW and IVA, while between IVA and IVB did not differ significantly (table 3).

Table 2: Tests of between-subjects effects using three-way ANOVA

Source	Mean square	Sig.
Corrected Model	19.735	.000
Intercept	187403.840	.000
Light curing source	44.165	.000*
Irradiation Time	3.072	.134
Shade	80.985	.000*
Light curing source * Irradiation time	1.323	.324
Light curing source * Shade	3.201	.098
Irradiation time * Shade	.003	.998
Light curing source * Irradiation Time * Shade	.075	.946
Error	1.350	
Total		
Corrected Total		

a. R Squared =.598 (Adjusted R Squared =.557), *significant at P<0.05

Table 3: Tukey HSD post hoc test between shade

Comparison between shades		P-value
IVW (whiter)	IVB (medium)	.000*
	IVA (darker)	.000*
IVB (medium)	IVA (darker)	.602

*Significant at P<0.05

DISCUSSION

Light-activated polymerization of bulk-fill resin-based nanohybrid composites can enhance heat generated by both the exothermic reaction and the light source. If the heat generated during polymerization exceeds the critical pulp temperature, it can harm the pulp tissue [14-18]. Based on table 1 in this study it showed that the irradiation with the QTH and LED light sources have a significant difference to the under-surface temperature of the bulk fill resin composites. The LED produces a higher under-surface temperature than QTH. In line with study conducted by Koumpia *et al.* reported that the irradiation with LEDs resulted in a higher under-surface temperature compared to the QTH. LED light with high intensity caused a higher temperature rise than QTH light with lower intensity [19].

The increase in the under-surface temperature during polymerization with either the LED curing unit or QTH light did not exceed the pulp threshold of 42,5 °C so it did not cause damage to pulp tissue. This may due to the heat generated by the curing unit during polymerization will be received by the dentin and then the heat will be reduced when it reaches the pulp. The components in bulk-fill resin composites have been modified compared to conventional resin composites [3, 15]. Increasing the amount of filler content and filler size in the bulk fill resin composite composition can also cause an increase in the contact area of the resin and filler; also reduce the amount of light transmittance into the resin composite. Light transmission is also reduced in composites with large fillers, causing the under-surface temperature of the bulk-fill resin composite to be low after polymerization [4].

Another study conducted by Wang *et al.* found that the type of light sources and the intensity of the light increased the temperature of each bulk-fill resin composite. The higher the light intensity, the higher the temperature. The increase in temperature during polymerization of the resin composite is a function of polymerization rate as a result of exothermic polymerization reaction and the energy absorbed during polymerization. An increase in light intensity means an increase in the energy density of light. This can result in more energy being absorbed during the polymerization process in the form of heat, causing an increase in temperature [20]. The critical temperature rise leading to pulp necrosis and the duration required is controversial. However, the increase in pulp temperature during polymerization of the composite resin should be kept as low as possible to avoid the risk of pulp damage [21].

It showed in table 2 that there was no significant difference in the surface temperature of bulk fill resin composites when irradiated with irradiation time of 20 s or 30 s using both light sources. Kim *et al.* stated that the temperature of bulk fill resin composites increases rapidly in the first 5 s when the light curing unit is activated and will experience a gradual decrease in temperature. This is due to the release of heat to the environment exceeding the heat generated from the polymerization process [13]. In a study conducted by Dikova *et al.* reported that the irradiation time for 20 s had a successful polymerization of bulk-fill resin composites with a minimum thickness of 47,1 mm and produced good mechanical properties [22].

In this study, there was an under-surface temperature difference in each shade of the bulk fill resin-based nanohybrid composite. This occured due to the type, amount of pigment and opacifier that provide varying shade effects cause differences in the absorption coefficient of each resin composite shade. The purpose of adding pigment is to visually color the teeth, while opacifiers are used to provide color perception according to the structure of the enamel and dentin. The pigments that are often used are the yellow pigment ferric oxide ($Fe(OH)3$) and the red pigment ferric oxide ($Fe2O3$) as well as the opacifier , which is titanium oxide and aluminum oxide in small amounts, which reduces the intensity of light required by the initiating agent during polymerization. The number of different pigments and opacifiers will affect the level of translucency in resin composite and light transmission. The more the number of opacifiers, the lower the translucency or even zero as a result of the large amount of light reflected by the opacifier so that the color of the resin composite looks whiter [1, 17].

The shade IVW of bulk fill resin composite (whiter shade) that is usually used for light-colored or primary teeth restorations in this study was found to produce the highest under-surface temperature. The ability of IVW shade to transmit light is quite high due to the low absorption coefficient and less pigment mixture compared to dark shade [1, 17]. Bright shades have a good speed to reach peak polymerization due to their higher translucency [1, 17, 23, 24].

On the other hand, shade IVA (dark shade) with the same thickness and irradiation time was found to produce the lowest under-surface temperature. This may be due to the shade IVA contains the most pigment among the others. Dark shade has a greater absorption of light and has a lot of light aberration by the pigment so that only a small amount of light is transmitted to the under-surface of the resin composite. This causes the transmission of light to take longer to reach the under-surface. Higher light absorption coefficient occurs in dark shade where the amount of light entering the under-surface also becomes lower. The incoming heat will also decrease to the under-surface [1, 17, 23, 24].

In contrast to this study, Hanum *et al.* reported that on conventional resin composite, the highest temperature of 52.70±2.30 °C was produced by dark shade (C3), followed by medium shade (A3) 50, 90±1.00 °C, while the bright shade (B1) produced the lowest under-surface temperature, which was 49.30±1.50 °C. Clinically, bright, medium, and dark shade in that study had different translucency with this study, and the irradiation was also carried out for 20 seconds with a thickness of 2 mm because adequate polymerization of conventional resin composite would only be achieved in 20 s. When the conventional resin composite polymerized for 20 seconds, the bright shade (B1) will polymerize faster because it has a higher translucency and transmit light more quickly to the under-surface so that at the end of the irradiation, there has been a decrease in temperature on the under-surface. In dark shade (C3) which has a lower translucency, high absorption of light occurs so that it stores the heat; adequate polymerization in dark shades tends to be achieved longer than bright shades which ultimately makes the highest temperature produced at the end of irradiation [17].

Shade IVW in this study resulted in the highest under-surface temperature compared to other shades. This temperature is still within the acceptable temperature range for the pulp, although it is close to the maximum limit. The light produced during polymerization can affect the under-surface temperature transferred to the heat. It may cause damage to the pulp chamber if the temperature produced is too high.

Thus, the causes of the increased under-surface temperature of bulk-fill resin composite include exothermic reactions and the use of light sources that can transmit different light for each bulk-fill resin composite shade [12, 13, 25]. In this study, shade IVW (whiter) produces the highest under-surface temperature, shade IVB (medium) produces the under-surface temperature between shade IVW (whiter) and shade IVA (dark shade), while shade IVA (dark shade) produces the lowest under-surface temperature. The three bulk-fill resin composite shades used in this study resulted in a temperature that the pulp could tolerate and were safe to use for restorations, requiring an irradiation depth of cure up to 4-5 mm.

The heat generated during polymerization is associated with tissue irritation and potential to cause damage. The degree of heat from light sources that can be tolerated by pulp during polymerization of bulk fill resin composite is still debated at this time. Many other factors can cause an increase in pulp temperature during the polymerization process of bulk fill composite resins, such as dentin thickness, composite resin shade and light intensity, so dentists need to avoid unnecessary procedures so as not to cause an increase in pulp temperature [16, 25].

CONCLUSION

It was concluded that

- Although LEDs generate a higher undersurface temperature of bulk fill resin composite than QTHs, both of them are safe for pulp tissue.
- Bulk fill resin composite irradiated for 20 seconds or 30 seconds are not significantly different to produce an under-surface temperature that will not damage the pulp tissue.
- All shades of bulk fill resin composites are still acceptable to the pulp tissue.

Nevertheless, the use of materials for pulp protection needs to be considered to prevent the higher under-surface temperature of bulk fill resin composite such as liner or base material.

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AUTHORS CONTRIBUTIONS

All the authors have contributed equally.

CONFLICT OF INTERESTS

All authors have none to declare

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