Original Article

Comparison of temperature rise in silorane-based and methacrylate-based composites cured by LED and Argon laser

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Abstract

***Background and Aim*:** Temperature rise occurs during photoactivation of dental composites due to the exothermic polymerization reaction and different curing units. The aim of this study was evaluation of temperature rise in two kinds of composites with different curing units.

***Materials and Methods*:** In this experimental study, five samples of each composite resin (Filtek Z250, Filtek P90) were placed in two-millimeter deep Teflon molds which were 4mm in diameter. Curing was done from top surface with LED, high power LED and argon laser and temperature was recorded by a thermometer placed under the samples. After reaching room temperature, samples were cured and the temperature was recorded again. The time of maximum temperature was also record ed. The data were analyzed by two-way ANOVA and Tukey HSD.

***Results*:** Composites and curing units had statistically significant influence on the temperature rise ($p<0.001$) Silorane-based composites showed significantly higher temperature rise than methacrylate-based ones. A significantly lower rise in tempera ture occurred when illuminationwas performed by argon laser. There was no signify cant difference in temperature rise between the two types of LEDs. The type of com posite had no effect on the time of maximum temperature and in all samples the max imum temperature was recorded at the beginning of irradiation.

***Conclusion*:** Silorane-based composites showed higher temperature rise than methacrylate-based ones. Argon laser revealed less heat than LEDs. The maximum temperature rise was recorded at the beginning of irradiation.

***Key Words*:** Polymerization - Temperature - Gas Laser - Filtek Silorane - Methacrylates

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Introduction

The increasing rate of production of light-activated dental materials has made curing units essential and common devices of each dental office. They are used to polymerize light-activated composite resins, resin activated glass ionomers and bonding systems [1]. Composites have gained popularity due to their low prices, conservative application technique and acceptable esthetics [2]. Polymerization of composites is a light-activated process. Adequate polymerization of light-cured materials is related to the light intensity, wavelength, and curing time [3]. Adequate polymerization of these materials provides improved physical and mechanical properties, decreased solubility, and increased biocompatibility and longevity of restorations [4] Studies have shown that curing units can cause a tem-

perature rise harmful for the pulp. An increase in the power of the available curing units may cause increased temperature beyond the pulpal resistance threshold. Quartz-tungsten-halogen (QTH) units are the most frequently used curing units in dentistry. The disadvantages of this curing system include an extremely low energy output in comparison with the consumed electrical energy, and increased operation heat build-up that harms both the curing unit and the dental pulp [5,6]. Therefore, QTH lamps have limited effective life and on the other hand, decreasing their light energy output with time causes a decrease in effective polymerization of the composite material [1].

Light-emitting-diode (LED) lamps are able to cure composites in lower temperatures. Effectiveness of the LED units is justified by their light emission spectrum which is more consistent with the standard absorbing light spectrum of the champhorquinone in comparison with that of QTH lamps. Contrary to the QTH lamps, no light is emitted within the spectrum of the infrared waves by LED units. Other advantages of the LEDs include increased lifetime, and more stable light energy output in comparison with QTH lamps [7] High-power LEDs are also available with a ligh intensity similar to that of QTH lamps [8].

Argon laser is a newer technology recommended to overcome the problems of composite polymerization. This system emits light energy in blue and green spectra. The blue spectrum of this laser beam has the ability to photopolymerize champhorquinone- containing composites, which is a unique feature among all laser types. The green light is applied for soft tissue management and blood coagulation [9]. Argon laser has properties such as being monochromatic and collimated. It also has a selective absorption [10]. There is an increased penetration possibility for the argon laser photons for curing purposes due to their visibility, consistency with the absorbing wavelength of camphorquinone, and a lower absorption coefficient in comparison with other wavelengths. Therefore, improvement of optical parameters can lead to more favorable curing degrees [11] The light intensity in QTH lamps and LED units attenuates with increased distance, but according to the optical properties of the laser beam, such beam attenuation is negligible in comparison with other light sources. Polymerization of composite resins cause heat buildup due both to the exothermic polymerization reaction and the energy absorbed from the curing light source which can be detrimental for the pulpal tissue. [14]

The objective of this study was to compare the temperature increase of the light-activated composite resins following use of LED and argon laser curing systems.

Materials and Methods

Two LED units and one argon laser curing unit was used in this experimental study. The features of the curing units are represented in table 1. The compose resins used were A2 shade Filtek Z250 (3M ESPE,USA) and Filtek P90 (3M ESPE,USA). The features of the composite resins used are also represented in table 2. Five samples with equal sizes of 4mm in diameter and 2mm in width were prepared in Teflon molds for each composite/curing unit combination at the room temperature. In each experiment, the upper surface of the composite was covered with a 0.03-mm thick translucent strip. Then, the conducting head of the light was placed in contact with the strip and parallel with the composite surface. Samples were cured according to the each manufacturer's recommendation. Polymerization temperature was measured by a k-type thermocouple fixed at the bottom of the cavity and attached to a thermometer (CNY 502A1, Taiwan) and showed in a monitor. The accuracy of the temperature measurement for the thermometer was 0.1 degrees centigrade. After initial

Table 1: Characteristics of the curing units used in this study

Curing unit	manufacturer	Unit type	Curing procedure
Ultralume2	Ultradent,USA	LED	40s-450mw/cm^2
Bluephase 16i	Ivoclar- Vivadent , Liechtenstein	High-power LED	10s-1800mw/cm^2
Melles Griot	USA	Argon laser	40s-500mw/cm^2

Table 2: Characteristics of the composites used in the study

Commercial name	type	resin	Filler composition	Filler size (µm)	Volume percent of filler content	Weight percent of filler content
P90	Low shrinkage posterior restorative	Silorane	Quartz, yttrium fluoride	0/1-2	%55	%76
Z250	Hybrid	Bis-GMA, UDMA, Bis-EMA, TEGDMA	Zirconia/ Silica	0/01-3/5	%60	%78

curing in the suggested times and recording the temperature rise, a time was given for the samples to cool down for five minutes to their original temperature before curing for the second step with the previous curing time. The temperature rise was recorded for the second time. Temperature rise in the primary step of curing is due to light emission of the curing unit and polymerization reaction. The resultant temperature increase within the next step is mainly due to the curing unit because the polymerization procedure is almost maximally completed. Therefore, it is possible to measure the temperature rise due to curing procedure separate from that of polymerization reaction.

The quantitative variables were reported as mean (±SD). Two way analysis of variance was used to evaluate the effects of curing unites and composites on the temperature increase, but due to the significance of the interaction of independent variables in the statistical analyses, the strategy for statistical analysis was shifted to one-way analysis of variance (to compare the effects of the three curing units) and independent t-test (to compare the effect of the composite type). According to the increased number of comparisons and the change in statistical strategy, the statistical significance level was considered 0.01 instead of 0.05.

Results

In this study, the primary temperature increase was related to both polymerization reaction and the curing unit and was referred to as T1. The temperature increase resulted from the curing unit during the second lighting procedure through the polymerized material was designated as T2. T3 was the difference between T1 and T2 and showed the temperature rise due to the polymerization reaction. T_{max} was a time when the maximal temperature was recorded.

In all three curing units, the type of composite had a significant effect on T1 and T2. (p=0.001) In all three curing units T1 and T3 were significantly higher in P90 group in comparison with Z250. In none of the curing units, the composite type had a significant effect on T2. P-values for the LED, high-power LED and argon laser units were 0.96, 0.80 and 0.13, respectively. In both composite types, the curing units had a significant effect on T2 ($p<0.001$) with argon laser system producing less temperature increase com

Table 3: Maximum total temperature increase (T1), maximum temperature obtained from the curing unit (T2), maximum temperature due to polymerization reaction (T3) and the time required to reach the maximal temperature (Tmax) using different curing systems.

Curing unit	composite	T1(°C)	T2(°C)	T3(°C)	Tmax (seconds)	N
LED	Z250	11/43±0/83	7/88±0/78	3/5±0/77	7/7±0/82	**5**
	P90	21/45±2/02	7/86±0/78	13/59±1/83	8±1/05	**5**
High Power LED	Z250	11/81±1/49	7/72±0/72	4/09±1/51	4/4±0/52	**5**
	P90	26/25±1/75	7/62±1/02	18/63±2/24	4/3±0/48	**5**
Argon Laser	Z250	7/86±0/95	3/41±0/36	4/45±0/93	8/4±0/96	**5**
	P90	13/12±1/7	3/17±0/35	9/95±1/87	9/7±1/15	5

Discussion

The aim of this study was to evaluate the temperature increase in Filtek P90 and Flitek Z250 composites while curing with two LED and one argon laser curing systems. In this study, the total temperature increase due to the curing unit, and polymerization reaction as well as the time required to reach the maximal temperature in composite samples was measured.

Temperature increase during restoration with light-activated composite resins is related to two factors; the exothermic polymerization reaction, and the output heat produced by the curing system [14]. Other factors such as the composite type, its thickness and color, curing time and the distance to the curing source are influential in the buildup of heat after use of composites [15]. In this study, the composite type had a significant effect on the total increase in temperature and the temperature increase due to polymerization in all curing units but was not effective in the temperature of the curing unit itself.

Higher increase in polymerization temperature of silorane-based composite P90 can be attributed to its difference in polymerization reaction which is based on siloxane and oxirane through a pared to the other LED systems. Type of composite was not significantly effective on T_{max} in any of the curing systems. (See table 3)

tring opening cationic reaction. This reaction occurs in the oxirane residue [16]. Optical pyrometric studies show that the ring opening cationic reaction of the oxirane is severely exothermic resulting in a heat buildup of 100 degrees centigrade at room temperature [17]. Further, the amount of heat produced during cationic polymerization is positively related to the number of photo-initiators [18]. This finding is in accordance with that of Vesna Miletic in 2009 who compared the increased polymerization temperature of Silorane, Ormocer and dimethacrylate based composites and concluded that P90 had a higher temperature increase in comparison with Admira (Ormocer) and Herculite XRV (a methacrylate-based dental composite). The other two materials did not differ in terms of polymerization temperature increase. In this study, only one high-power LED (Bluephase) was used and the curing time was 20 seconds [19]. The type composite did not have any significant effect on T2 (the temperature increase due to the curing unit) in any of the groups using different curing units. This finding is logical because T2 is a temperature rise measured after polymerization of the composites and therefore is related to the curing unit only. At this time, the composites are maximally polymerized and the resultant heat is dissipated after cooling down of the samples to the room temperature. T2 is a heat produced as a result of light emission from the curing units, therefore the composite type and the increased temperature due to the polymerization process is not influential in T2. This finding is congruent with Khezevic's study in 2005 in which the kinetics of temperature increase following polymerization and a second-time curing did not signifi-

cantly change with different curing modes [20]. On the contrary, this finding is in contrast with a study conducted by Tabatabaee and co-workers in 2009 in which the curing unit-induced heat was influenced by the type of composites used. This difference might have been attributable to the difference in particle type and size of the composites used which could have caused differences in opacity and/or variability in diffraction of the transmitted curing light through the composites used [21]. Accordingly, it seems that both Z250 and P90 composites have similarities in terms of light diffraction and transmission.

The highest temperature increase (T2) was recorded for LED and high-power LED curing units and the lowest for the argon laser unit, for both composite types. There was no significant difference between two LED systems in T2, but the argon laser system showed a significantly lower temperature increase. This was in accordance with Rasteli et al. in their study, curing was performed by argon laser, QTH, and LED units through cured Z250 composite samples at five, ten, twenty, thirty, forty, fifty and sixty seconds and the temperature increase was recorded. The highest temperature increase was recorded for QTH, LED and argon laser, in a descending order [22]. Argon laser emits a light spectrum within the wavelength of 488nm and is in accordance with the maximal absorption spectrum of CQ which is within the range of 468-492nm. The total light produced by the argon laser unit is a usable energy; therefore, less heat is absorbed by the pulp. It has been shown by some studies that better clinical results can be obtained by argon laser units due to better energy distribution and less heat buildup within the pulp [23]. None of the composite types had a significant effect on T_{max} when different curing units were utilized. The time when maximum temperature increase is reached (T_{max}) provides suitable information about the pre-gel stage. In polymerization of the dental composites, the gel area is of utmost importance in compensation of the polymerization stresses [24]. In both composites used, the maximal temperature was recorded in initial stages of the curing process when LED and argon laser systems were used. This occurred regardless of the composite used. Knezevic also reported that the maximum temperature increase following polymerization occur within the initial few seconds and then decreases thereafter [20]. In addition, Pilo and Sakaguchi stated that the rapid increase in temperature during initial 20-30 seconds is dependent upon the curing light emission intensity and reaches a plateau within 50 seconds [24,25]. In a study by Tabatabaee et al, the maximal polymerization temperature was reached in a longer period of time in a nano-filled (Filtek Supreme) composite in comparison with a hybrid (Tetric Ceram) composite. This can be related to the slower process of polymerization due to smaller nano-sized fillers and their increased efficient surface [21]. It should be noted that in the current study, increased temperature of the composite was measured without considering the temperature changes of the dental tissue. Clinically, dentin prevents heat to be transferred to the pulp due to its low thermal conductivity, but in deep cavities an increased potential exists for thermal damage to the pulp due to reduced remaining dentin thickness and increased tubular surface [26].

Conclusion

1.Argon laser and LED curing systems provide the lowest and highest temperature increase during polymerization procedure in both composite samples, respectively.

2.P90 composite sample showed a significantly higher temperature increase in comparison with Z250, regardless of the curing unit. Therefore, the composite type was significantly influential in increase of temperature following polymerization. As a result, P90 composite should be used with caution in deep cavities.

3.The maximal thermal increase was considered to happen within initial curing stages in both composite samples and all curing units.

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