ORIGINAL ARTICLE

Comparative Effectiveness of Two Light Curing Units on the Properties of Dental Resin Composites

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ABSTRACT

Background: Setting of conventional glass ionomers cement and dental resin composites as filling materials is predominantly through polymerization reaction, which is usually induced by light. The objective of this study was to assess the temperature changes, light intensities, sorption and solubility capability and comparative micro hardness in Dental Resin Composites (DRC) by using two different light curing units that is Quartz Tungsten Halogen (QTH) and Light Emitting Diodes (LED).

Methods: This analytical, experimental, in-vitro study was spanned over one month, conducted in the laboratory of Dental Materials, Dr. Ishrat-ul-Ibad Khan Institute of Oral Health Sciences. Through non-probability, convenient sampling, 60 samples of DRCs was prepared as 10mm in diameter and 2mm in thickness in the steel moulds by a single trained operator. Effect of heat generation, light intensities, sorption and solubility and micro hardness during polymerization of DRCs were all measured. Statistical analysis was done using SPSS with descriptive statistics and two sample independent t-tests. The *p*-value of <0.05 was considered significant at 95 % confidence level.

Results: Mean surface micro hardness of DRC was found to be 15.48±0.46 and 18.26±0.53 when QTH and LED lamps were employed respectively. Whereas, mean light intensity of QTH and LED lamps were found to be 434 and 925mW/cm^2. No significant difference in temperature change during polymerization reaction ($p=0.128$) and in sorption and solubility capability ($p=0.001$) of DRC was observed.

Conclusion: Light-emitting diodes were evaluated to be more effective than Quartz Tungsten Halogen Light in achieving increased surface micro hardness of DRC.

Keywords: Light; Glass Ionomer Cements; Tungsten; Hardness.

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doi.org/10.36283/PJMD9-4/011

INTRODUCTION

Conventional Glass Ionomers Cement (CGIC) has an established legendary role as filling material to control and prevent active and recurrent dental caries[1]. In primary dentition and in those patients, which are at high risk of dental caries, Glass Ionomers Cement (GIC) is more recommended because of its fluoride releasing ability, shorter setting time, less technique sensitivity and good aesthetics[2]. However, CGIC produce some limitations because of its compromised mechanical and physical properties and reduce moisture sensitivity[3]. Dental Resin Composites (DRC) also known as Resin Modified Glass Ionomer Cements (RMGIC) were introduced as a solution to this having 4.5 to 6% polymerizable resin which gives the material more strength and hardness[4-6].

Setting of CGIC and DRC materials is predominantly through polymerization reaction; however, acid base reaction is also involved partially in setting of GICs[7,8]. For better aesthetic, introduction of optical properties in DRC has a significant effect with polymerization of filling materials[9]. This polymerization reaction is usually induced by light. Exposure time of curing light and curing method, depth of light penetration and intensity of light curing lamps has great impact on the degree of conversion of monomer units into polymer and the ultimate surface micro hardness and intrinsic strength of the filling material[10]. Incomplete curing leads to increase water sorption and solubility of the filling material effecting the ultimate strength and hardness[11-14].

Water sorption property in the composite resin is reported to be a diffusion-controlled process. In this process, the chemical breakdown in the structure of the material may results in numerous ultimate shortcomings such as compromised mechanical property of the material. Research showed that this is mainly related to the debonding in filler and matrix polymerization reaction and release of residual monomer. On the other hand, solubility in composite also contributes in leaching of residual monomer and loss of filler. This water sorption and solubility effects the durability and strength of DRC[15].

Previously, Quartz Tungsten Halogen (QTH) lights were used for curing DRC having major advantage of low-cost technology and 40 to 100 hours half-life with filters and ventilating fans for cooling[12]. However, in 1990's Light emitting diodes (LED) was introduced having more incredible and durable properties of around 10,000 hours half-life, reduced curing time and decreased heat from cordless light tip with no filters because it emit light with narrow beam resulting in less heat generation[14,16,17]. Entire resin restorative material (full thickness) can be polymerizing using LED light[18].

Literature suggests that as the polymerization reaction occurs in DRC from different light curing units it results in noticeable heat generation[19]. This polymerization reaction heat has been studied in many researches, which concluded that this heat is responsible for adversely affecting the dental pulp and can cause thermal injury to this live tissue[20]. Heat liberated during this reaction is diffused to the pulp through the surrounding dental tissues. The increased heat in the pulp chamber during polymerization is also being recognized as a crucial etiological factor for such injuries while using DRC[19]. Taher et al., studies also reported irreparable pulpal impairment in 15% of the teeth under observation when temperature was elevated to 5.6-degree centigrade[21]. It is therefore recommended to measure this heat liberation in order to subside the possibility of thermal pulp injury during the curing reaction of resin composites[18-21].

The modern dental community is still not aware of using latest technology while handling sensitive dental materials for the restoration of teeth. Compatibilities of QTH or LED with DRC still need to be explored for an ultimate high strength and durable dental restoration. Therefore, the objective of the study was to assess the temperature changes, light intensities, sorption, solubility and comparative micro hardness in dental resin composites using quartz tungsten halogen light and light emitting diodes.

METHODS

This analytical, experimental, in-vitro study was over all spanned over one month. The samples were prepared in the laboratory of Dental Materials, Dr. Ishrat-ul-Ibad Khan Institute of Oral Health Sciences (DIKIOHS). However, due to non-availability of the required testing facility in DIKIOHS, the testing was performed at NED University of Engineering and Technology, Karachi. Approval to conduct this study was obtained from the Ethical Committee of DIKIOHS under letter number IRB–567/DUHS /approval/2015.

Through non-probability, convenient sampling, 60 samples of DRC was prepared in the steel moulds. A single trained operator mixed the material according to the manufacturer's instruction. These DRC samples were prepared as 10 mm in diameter and 2 mm in thickness in a disc shape cavity designed in the steel moulds and were placed over the glass slabs[5]. However, all other disc which were not prepared as per the required measurements were excluded. Out of 60 prepared samples, 30 were then covered with glass slide at the top before curing in order to have good adaption of material into the mould and to have a flat and smooth surface. In the rest 10 samples, thermocouple wires were placed 0.5 mm deep from the base of the mould. At every step, photo activation with QTH and LED was performed for 40 seconds.

For testing the temperature changes (heat liberation) in the DRCs, 10 samples with placed thermocouple wires were divided into two groups having 5 samples each. Group A was later exposed with QTH while group B was exposed with LED. The wires were then attached to the Thermocouple unit of K type, SE 112 (BBC GOREZ Metrawatt, Austria) before exposing the samples LCUs. Tips of both the curing lamps were in close contact with the DRC samples under controlled temperature (37°C) and humidity in the laboratory. Initial temperature was noted after which photo activation was performed and temperature peak was noted. Four different readings were taken for each group to calculate the ultimate mean temperature change. Initial temperature was later subtracted from these four noted temperature readings[21].

The intensity and degree of light penetration of both devices were measured according to "International Organization for Standardization" as ISO 4049. As per their avocation, at the tip of the Light curing units (LCUs) the intensity was 300mW/cm^2 and the wavelength ranged from 400 to 515 nm. At this set standard, the penetration was 1.5 mm. For all this analysis, 0 to 1000 mW/cm^2 ranged analog radiometer "DigiRate, Monitex, Taiwan" was employed which took 4 consecutive reading to obtain the mean intensity[16,17].

The sorption and solubility tests were performed by following the standard method ISO4049:198815 and were measured by using water as solvent under conventional curing mode with constant energy density. The left 20 DRC samples (from the total 60) were divided into two groups having 10 samples each. Group A samples were exposed with QTH while group B discs were exposed with LED. After curing all samples were placed into two open glass bottles of 20mm, which were marked as A, and B. These glass bottles were next inserted into fresh silica containing desiccator. The desiccator was later placed into an oven at 37±1˚C for 24 h. After this, the desiccator was removed from the oven and glass bottles were placed on a bench at room temperature (25±1˚C) for next 24 hours. After a complete cycle, all samples were weighted on calibrated analytical balance. This whole process was repeated until a constant mass (M1) was obtained. After that, to each glass bottle 10 ml of deionized water was added and placed in oven at 37±1˚C for 7 days. After 7 days, the glass bottles were removed from the oven and placed on a bench at room temperature (25±1˚C). To calculate the M2 (mass of after storage), specimens were removed from the glass bottle and dried by using absorbent paper. The weight of these specimens provided the value of M2. Further, these specimens were placed into fresh silica containing desiccator and same route was adopted as for M1 to get a constant weight. This obtained constant weight after the evaporation of water is now M3. Water sorption and solubility capability of DRC were next determined by using the already reported following equations: Wsp = M2-M3/V; Wsl = M1-M3/V. Whereas, Wsp shows the sorption, Wsl shows the solubility, M1 was the initial mass, M2 shows the mass of after storage with water for 7 days, M3 was the final mass obtained after the evaporation of water[22]. All three masses were obtained in mg, whereas, the V shows the volume of specimen in mm^3.

In order to check the micro hardness, out of 30 non-wired samples, 15 were placed Group A and were cured using QTH light, while the rest of the samples (n=15) were placed in Group B and were cured using LED light. After curing, the samples were detached from the mould and stored in a black jar (to avoid light reaction) filled with distilled water for 24 hours. The samples were tested using the Micro Vickers Hardness Testing Machine. Four notches were taken on each sample for testing and the mean was then calculated[23]. The analysis was done using Statistical Package Social Sciences version 21 and included descriptive statistics along with two sample independent t-tests to identify the mean difference between the two groups. The *p*-value of <0.05 was considered significant at 95 % confidence level.

RESULTS

Mean change in temperature during polymerization reaction (Table 1 and Figure 1) reported when QTH and LED lamps was suggested a non-significant difference in the mean temperature change with two light sources.

Table 1: Mean temperature change during polymerization reaction and light intensity measurement for quartz tungsten halogen (QTH) and light emitting diodes (LED) in Group A and B.

Groups	Light Source	Temperature Change (°C) Mean ± SD	*p*-Value	Light Intensity (mW/cm^2)*	*p*-Value	Micro Hardness (MPa) ** Mean ± SD	*p*-Value
Group A	QTH	7.26±1.23	*0.128	434	*0.001	15.48±0.03	*0.000
Group B	LED	7.35±1.32		925		18.26±0.03	

*p-value = Level of Significance; * Milliwatts per centimetersquare, ** Mega Pascal.*

 doi.org/10.36283/PJMD9-4/011

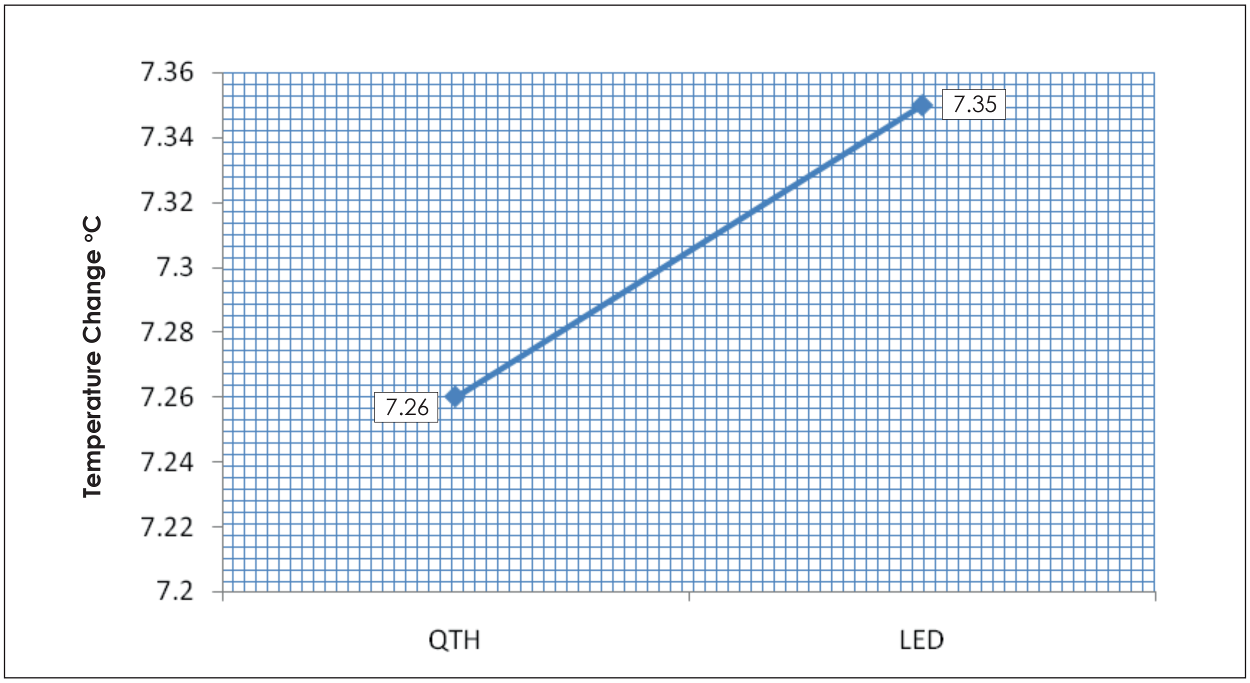

Figure 1: Mean temperature change in °C during polymerization reaction with quartz tungsten halogen (QTH) and light emitting diodes (LED).

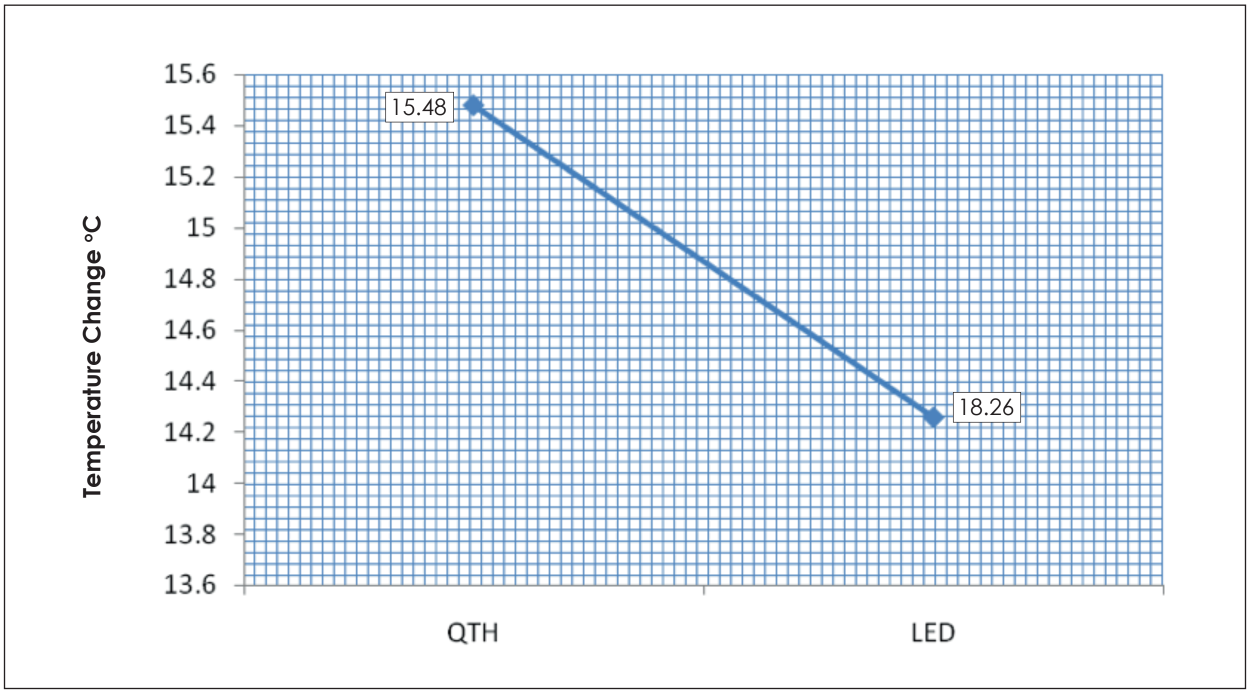

Figure 2: Mean surface micro hardness in mega Pascal with quartz tungsten halogen (QTH) and light emitting diodes (LED).

Mean surface micro hardness of DRC achieved using (Table 1 and Figure 2) QTH light with the results of independent t-test revealed a significant difference (*p*-value=0.000) in the mean surface micro hardness of the sample material when two different light curing units were used. Mean sorption and solubility capabilities of DRC (Table 2) indicated a insignificant statistical difference between the two samples (*p*=0.001).

Table 2: Mean for water sorption and solubility in μg/mm³ for 7 days under conventional curing mode.

Groups	Light Source	Sorption	*p*-Value	Solubility	*p*-Value
Group A	QTH	7.27 ±0.95	0.001	1.62 ± 0.78	0.001
Group B	LED	7.82 ±0.98		1.60 ± 1.48	

DISCUSSION

This study has identified no significant change in temperature and sorption and solubility capabilities but increased micro hardness of DRC when cured with LED light as compared to QTH light. Mean micro-hardness measurements are found to be significantly different in both groups. Measured micro-hardness is the true reflection of a material's mechanical strength[14].

Significant difference was also observed between the mean intensities of QTH and LED lamps suggesting the more efficiency of LED over QTH light source. The reported results of the current study are in line with the previous literature, which also advocated the superior effectiveness of LED in comparison to QTH light curing units[23].

In current study, no significant temperature change was observed in both the groups. This is contrary to the findings of the study, which reported that LED unity resulted in higher temperatures as compare to heat liberation with QTH. A possible explanation to this difference could be higher light intensity of LED unit obtained in this study. This over result suggests that it is safe to use both the light sources without having pulpal insult[21]. The sorption and solubility capability under conventional curing mode by using water as solvent did not change in both QTH and LED. These results are in accordance with the already reported literature, thus suggesting reliability of findings[22, 24].

The effective curing of resin material can be calculated using direct or indirect method[16]. In comparison to indirect methods, direct resin curing methods are more intricate, costly, and consume more time[17]. In the present study, resin cements are dually cured as it allows improved regulation throughout the cementation technique. This type of curing is more effective in penetrating deeper zones where usually the single curing light cannot infiltrate. Furthermore, the self-curing method of several dual-cure cements is usually insufficient and, in such cases, the additionally provided light may function as a supplementary effect of resin curing[25].

In addition to this, the samples are prepared as recommended in a thickness of 2mm. The evidence that hardness of material reduces intensely when its thickness is more than 2mm supports this[26]. Irrespective of which light-curing unit is utilized, undesirable consequence is reported on the resin curing depths and hardness when there is increase in material thickness[27]. Moreover, in building restorations, which are more than 1 mm in thickness, the material should incorporate a self-curing catalyst above the light-curable portion, since it gives increased curing depth and surface hardness[28]. Apart from this, following the suggested time when using curing lights may produce required hardness of material even when cement is used in thick increments in lower areas of restoration. In order to achieve desirable clinical results and superior mechanical properties it is therefore endorsed that while using DRC, clinicians must use dual-cure materials and curing lights of high-intensity[27,28].

Likewise, different curing lights may affect the vickers surface hardness. Evidence suggests greater hardness on the top surface of restoration, which is effectively light stimulated[19,29]. Although in routine clinical cases, the cements are used in thin segments, but this is not always the same. Some indirect restorations do not always possess uniform thickness because of poorly defined cavity shape and occlusal imbalance[30]. In order to attain increased mechanical strength of the material (DRC) in terms of micro hardness, LED light must be preferred in comparison to QTH light in routine dental practices. In the present study, the hardness of cement in deeper areas of restoration was not been studies and therefore suggested to be further evaluated in future similar studies. Therefore, we recommended that comparative studies might be carried out to evaluate the effect of bonding agent on DRC samples using the LED source of curing unit. Since, the current study has revealed the effect five major variables responsible for the success or failure of a very common filling material used in dental offices by general practitioners.

CONCLUSION

Light-emitting diodes were evaluated to be more effective than Quartz Tungsten Halogen Light in achieving increased surface micro hardness of dental resin composites. A statistically significant difference was obtained in the mean light intensities, whereas, no difference was found in the temperature change during the polymerization reaction and in the sorption and solubility of dental resin composites; when the two different light sources were engaged.

ACKNOWLEDGEMENTS

Heartfelt thanks to the platforms of Dr. Ishrat-ul-Ibad Khan Institute of Oral Health Sciences and NED Engineering University, Karachi, for giving us opportunity to perform the required laboratory tests for this study.

CONFLICT OF INTEREST

There is no conflict of interest among the authors.

ETHICS APPROVAL

The study obtained the approval from the Ethical Committee of DIKIOHS under letter number IRB–567 /DUHS /approval /2015.

AUTHORS' CONTRIBUTION

All the authors contributed equally in this research manuscript.

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