Effects of Light-Curing Techniques on Dental Resins - A Cross-Sectional Study

Abstract

Background: Commonly used dental resin composites are used as dental filling materials with the help of light induced polymerization reaction. The purpose of this cross-sectional research was to compare the results of different light intensities on the hardness of different dental composites. Following light treatment units were used.

- QTH also called Quartz Tungsten Halogen
- LED also called Light Emitting Diodes

Methods

This one-month cross-sectional, in-vitro study was carried out in the Dental Materials Laboratory at King Saud University in Saudi Arabia. Using non-probability, convenient sampling, a single trained operator prepared 60 dental restorative composites (DRC) samples in steel molds with a diameter of 10mm and each mold was 2mm thick. During the polymerization of DRCs, the effects of light intensities, sorption and solubility, and microhardness were all measured. SPSS was used for statistical analysis and a p-value of <0.05 was declared striking.

Results

When QTH and LED lamps were used, the average micro hardness of DRC was estimated to be 15.480.46 and 18.260.53, respectively. The mean light intensity of QTH was 434 mW/cm^2 and for LED lights it was 925mW/cm^2. There was no notable difference in DRC sorption and solubility capability (p=0.001) during the polymerization reaction (p=0.128).

Conclusion

When it came to increasing the surface micro hardness of DRC, LED light was found to be more effective than QTH light.

Introduction

Conventional Glass Ionomers Cement (CGIC) has a long and illustrious filling material for active and recurring dental caries (1). Because of its fluoride-releasing capabilities, quicker setting time, lower technique sensitivity, and good aesthetics (2), Glass Ionomers Cement (GIC) is more suggested in primary dentition and patients at high risk of dental caries. However, CGIC has some limits and reduces moisture sensitivity because of its degraded mechanical and physical qualities (3). Dental Resin Composites (DRC), also known as Resin Modified Glass Ionomer Cements (RMGIC), were developed to solve this problem, containing 4.5 to 6% polymerizable resin that increases the material's strength and hardness (4)

The polymerization reaction is primarily responsible for CGIC and DRC materials; however, the acid-base response is also involved in the setting of GICs (5, 6). Optical qualities to DRC have a considerable impact on the polymerization of filler materials for improved aesthetics (7). Light is frequently used to initiate this polymerization activity. The degree of conversion of monomer units into the polymer, as well as the ultimate surface microhardness and intrinsic strength of the filler material, are greatly influenced by the curing time and procedure, depth of light penetration, and intensity of light-curing lamps. Incomplete curing increases the filler material's water sorption and solubility, lowering its ultimate strength and hardness (8, 9) .

The water sorption property of the composite resin is said to be controlled by diffusion. The chemical breakdown of the material's structure during this process can lead to various issues, including a material's mechanical properties being impaired. According to research, this is mainly due to debonding in the filler and matrix polymerization reactions and the release of residual monomer. Solubility in composites, on the other hand, contributes to residual monomer leaching and filler loss. The durability and strength of DRC are affected by its water sorption and solubility (10).

Before this, DRC was treated using QTH lights, which had the advantage of being economical and having a half-life of 40 to 100 hours and filters and ventilation fans for cooling (9). However, in the 1990s, light-emitting diodes (LEDs) were introduced, which had more remarkable and durable properties, such as a half-life of around 10,000 hours, reduced curing time, and reduced heat from cordless light tips with no filters, because they emit light with a narrow beam, resulting in less heat generation (11) . LED light may polymerize the entire resin restorative material (total thickness) (12).

According to the literature, the polymerization process in DRC from various light-curing devices results in significant heat generation (13). Many studies have indicated that the heat produced by the polymerization reaction is responsible for negatively influencing the tooth pulp and can cause thermal harm to this vital tissue (14). The heat released during this reaction is distributed to the pulp via the oral tissues surrounding it. During polymerization, increased heat in the pulp chamber has also been identified as a critical etiological element in DRC19-related injuries. When the temperature was raised to 5.6 degrees Celsius, Taher et al. found irreversible pulpal deterioration in 15% of the teeth under observation (15). Therefore, it is advised that this heat liberation be measured to reduce the risk of thermal pulp injury during the resin composites curing reaction (15).

The current dental community is still unaware of the importance of employing cutting-edge technology while working with delicate dental materials for tooth repair.

For ultimate high strength and enduring dental restoration, compatibilities of QTH or LED with DRC must yet be investigated. Using QTH and LED lights, the study evaluated temperature variations, light intensities, sorption, solubility, and comparative microhardness in dental resin composites.

Methodology

This analytical, experimental, in-vitro study took a month to complete. The samples were prepared at King Khalid University's Dental Materials Laboratory. 60 DRC samples were made in steel molds using non-probability, easy sampling. A single skilled operator mixed the material. These DRC samples were made in a disc shape cavity constructed in steel molds and set over the glass slabs (16).

On the other hand, all other discs that were not made according to the required measurements were disqualified. Thirty of the 60 created samples were then covered with a glass slide at the top before curing to ensure good material adaptation and a flat and smooth surface. The thermocouple wires were positioned 0.5 mm deep from the mold's base in the remaining ten samples. Photoactivation using QTH and LED was done for 40 seconds at each step. Ten samples with thermocouple wires were separated into two groups of five samples each to examine temperature variations (heat liberation) in the DRCs. After that, group A was exposed to QTH, whereas group B was subjected to LED. Before revealing the samples LCUs, the wires were linked to the Thermocouple unit of K type, SE 112 (BBC GOREZ Metrawatt, Austria). The tips of both curing lamps were in close contact with the DRC samples in the laboratory, which were kept at a constant temperature (37oC) and humidity. The initial temperature was recorded, followed by photoactivation and the measurement of the temperature peak. To compute the ultimate mean temperature change, four separate observations were taken for each group.

Both devices' intensity and degree of light penetration were assessed using ISO 4049, a standard mentioned by the "International Organization for Standardization." According to their profession, the power at the tip of the Light curing units (LCUs) was 300mW/cm^2, and the wavelength ranged from 400 to 515 nm. The penetration was 1.5 mm at this specified standard. The mean intensity16,17 was calculated using a 0 to 1000 mW/cm2 ranging analog radiometer "DigiRate, Monitex, Taiwan" that took four consecutive readings (17).

The tests for sorption and solubility were conducted according to the standard method ISO4049:198815, with water as the solvent and a constant energy density in the usual curing mode. The remaining 20 DRC samples (out of 60) were separated into two groups, each with ten samples. The samples in Group A were exposed with QTH, whereas the discs in Group B were exposed with LED. After curing, all samples were separated into two 20mm open glass bottles labeled A and B. These glass bottles were then placed in a desiccator that contained fresh silica. The desiccator was then placed in a 371°C oven for 24 hours. The desiccator was then taken out of the oven, and the glass bottles were placed on a bench at room temperature (25°C) for the following 24 hours. After the cycle was completed, all samples were weighed on a calibrated analytical balance. This technique was continued until the mass (M1) remained constant. After that, 10 mL of deionized water was added to each glass container and baked for seven days at 371°C. After seven days, the glass bottles were taken out of the oven and placed at room temperature (25°C). Specimens were taken from the glass bottle and dried using absorbent paper to compute the M2 (mass after storage). The weight of these specimens determined the value of M2.

To obtain a constant weight, these specimens were put in a fresh silica-containing desiccator and processed the same as M1. After the evaporation of water, the resultant stable weight is now M3.

The following equations: $Wsp = M2 - M3/V$; $Wsl = M1 - M3/V$, was used to evaluate the water sorption and solubility capabilities of DRC. Wsp indicates the sorption, Wsl indicates solubility, M1 is the starting mass, M2 is the mass after seven days of storage with water, and M3 denotes the final mass after water evaporation (18). The groups of all three specimens were measured in milligrams, whereas the specimen volume was measured in $mm^{3.}$

To determine the microhardness, 15 non-wired samples were assigned to Group A and cured with QTH light, whereas the rest of the samples (n=15) were designated as Group B and cured with LED light. After treatment, the pieces were stored for 24 hours in a dark jar filled with distilled water (to avoid light response). The Micro Vickers Hardness Testing Machine was used to test the samples. Each sample had four notches cut out for testing, and the mean was calculated (19). The study used version 21 of the Statistical Package for Social Sciences. It included descriptive statistics and two-sample independent t-tests to determining the mean difference between the two groups. A p-value of < 0.05 was declared significant.

Results

When QTH and LED lamps were used as light sources, the mean temperature change during the polymerization reaction (Table 1) revealed a non-significant difference in the mean temperature change. DRC's mean surface microhardness was determined utilizing (Table 1). When two different lights were used, QTH light with the results of an independent t-test demonstrated a significant difference (p-value=0.000) in the mean surface microhardness of the sample material. DRC sorption and solubility characteristics (Table 2) revealed a statistically negligible difference between the two samples (p=0.001).

Table 1:

Mean temperature change during polymerization reaction and light intensity measurement for QTH and 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	*0.128	925	*0.001	18.26±0.03	*0.000

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

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

When DRC was cured using LED light instead of QTH light, there was no significant difference in temperature, sorption, or solubility capabilities, but microhardness increased. The mean micro-hardness measurements in both groups are found to be considerably different. Micro-hardness is an accurate reflection of a material's mechanical strength when measured (20). There was also a noteworthy difference in the mean intensities of QTH and LED lamps, indicating that

LED lamps are more efficient than QTH lamps. The current study's findings are consistent with prior research, which has argued that LED light curing units are more effective than QTH light-curing units. In the current investigation, neither group experienced a substantial temperature change. This contrasts with the study's findings, which found that LED unity produced higher temperatures than heat liberation using QTH. This shows that both light sources can be used safely without causing pulpal insult (15). In both QTH and LED, the sorption and solubility capabilities in the traditional curing mode with water as the solvent did not change. These findings are consistent with previously published literature, implying that the results are reliable. The direct or indirect method can be used to calculate the adequate curing of resin material. Direct resin curing procedures are more complicated, expensive, and time-consuming than indirect methods (11).

Resin cement is dually cured in this study because it allows for better control throughout the cementation process. This method of curing is more successful in entering deeper zones where a single curing light would typically be unable to penetrate. Furthermore, specific dual-cure cement' self-curing approach is frequently insufficient, and in such circumstances, the additional light may serve as a supplementary effect of resin curing (21). Furthermore, the samples are produced to the recommended thickness of 2mm. Evidence suggests that when a material's thickness exceeds 2mm, its hardness decreases dramatically (22). When the material thickness increases, regardless of whether the light-curing unit is used, adverse effects on resin curing depths and hardness are reported (23).

Furthermore, in building restorations with a thickness greater than 1 mm, the material should include a self-curing catalyst above the light-curable component since this improves curing depth and surface hardness (24). Apart from that, utilizing curing lamps for the recommended duration may result in the required hardness of the material, even when cement is applied in thick increments in lower sections of the restoration. Clinicians are advised to employ dual-cure materials and high-intensity curing lights while utilizing DRC to get desirable clinical effects and superior mechanical properties (23, 24). Similarly, the surface hardness of Vickers can be affected by different curing lamps. Evidence suggests that the top surface of the repair, which is effectively light stimulated, has a higher hardness (25). Although the cement is usually utilized in thin segments in regular clinical cases, this is not always the case. Because of the poorly defined cavity shape and occlusal imbalance (17), some indirect restorations do not always have a uniform thickness. In everyday dental practices, LED light must be favored over QTH light to achieve higher mechanical strength of the material (DRC) in microhardness. The hardness of cement in deeper areas of repair was not studied in this study, and it is proposed that it be evaluated in future such investigations. As a result, we suggested that comparison studies be conducted to assess the effect of the bonding agents on DRC samples using the LED curing unit. Since then, the current investigation has demonstrated the impact of five important variables on the success or failure of a typical filling material used by general dentists in their offices.

Conclusion

When it came to increasing the micro surface hardness of dental resin composites, LEDs were more successful than QTH Light. A significant difference was there in the mean light intensities when the two different light sources were used. Still, no difference was found in the temperature change throughout the polymerization reaction or in the sorption and solubility of dental resin composites.

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