Original Article

The Effect of Different Light Curing Units and Composite Thicknesses on the Shear Bond Strengthof Composite to Dentin

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Abstract

Background and Aim: Development of new composite resins is one of the most important technological advances in the field of cosmetic dentistry. The aim of this study was to investigate the effect of different light curing units and composite thicknesses on the shear bond strength of composite to dentin.

Materials and Methods: In this experimental in-vitro study, the test groups were composed of 80 dentinal samples, prepared on occlusal surfaces of 80 maxillary premolar teeth and routinely divided into 8 groups of 10. Two cylindrical molds (2.5×2mm (in groups 1, 4, 5, and 6) and 2.5×5 mm(in groups 2, 3, 7, and 8)) were filled in bulk using P60 (groups 1, 3, 4, and 8) and Ceram X (groups 2, 5, 6, and 7) composites and light cured with LED (in groups (4, 6, 7, and 8) and QTH (in groups 1, 2, 3, and 5) light curing units .After curing and 3 months aging in 37°c water, shear bond strength of all samples were evaluated using a universal testing machine with 1mm/min crosshead speed. One- and three-way ANOVA were used for statistical analysis using SPSS software.

Results: The maximum (31.75 MPa) and minimum (15.34 MPa) mean of shear bond strength was in groups 1 and 7, respectively. Type and thickness of composites had significant effects on shear bond strength and no significant differences were found between two light curing units. (p<0/05)

Conclusion: The shear bond strengths of P60 and CeramX composites tested were much lower when cured in a 5-mm than in a 2-mm increment. The two types of light curing units tested did not show any significant differences in the amount of shear bond strength.

Key Words: Shear bond strength, Composite resin, Light curing unit

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Introduction

One of the most advanced technologies in cosmetic dentistry is the development of new composite resins, which has made a great revolution in photoactivation process [1]. Nowadays, it is believed that conversion degree of composites depends on some of their properties such as hardness, thickness, shear bond strength, and color of composites, as well as curing time, unit type, spectrum and wavelength [2]. Recently, some manufacturers have claimed production of composites which can be successfully cured in thicknesses of five mm and more while the maximum recommended thickness for most commonly used composites is 2 – 2.5 mm

(3). Furthermore, in a study, hardness of composite in depth of 4 mm was considerably less than that on the surface. In other studies, it was stated that conversion degree was about 50% in depth of 3 mm [3,4].

Light curing units (LCUs) called quartz tungsten halogen (QTH) systems are the most commonly used units in dentistry. QTH units produce a large amount of infrared light to warm the unit up, reduce intensity of external light and decrease lamp life time [5]. Dynamics of polymerization reactions depends on activation of their photosensitive component which is camphorquinone in most cases. This molecule can absorb energy at wavelengths between 400 and 500 nm [6].

It has been shown that LED devices convert more composite monomers into polymers compared with QTH units because the wavelength of their external light is fully consistent with absorption of camphorquinone [7,8].

The first generation of LED units had relatively low external power and some studies showed that their amount of radiation was similar to that of conventional light sources. The second generation of these devices used high-power light emitting diodes, which demonstrated better performance during a less curing time in comparison with the first generation. Recently, the third generation of LED devices has been marketed and it is claimed that they emit higher light intensity, which needs further investigations [9].

Franco et al. in 2007 examined the effect of three types of curing units (one QTH and two LED units) on composite tensile strength and microhardness and concluded that QTH device had better results [10]. Depth of curing depends on filler material and its chemical structure, color and translucency, light intensity and duration of light exposure [11].

The aim of this study was to investigate the effect of different curing units and composite thicknesses on shear bonding strength using LED and QTH.

Materials and Methods

In this experimental in-vitro study, 80 human pre molar teeth were collected and cleansed. After washing, they were kept in 0.5% hydrated chloramine T solution for one week. Their maximum storage time was three months before starting the study.

Before preparation, the teeth were thoroughly rinsed with water. Then, they were prepared by a diamond disk up to the nearmost half of DEJ to the pulp, to simulate depth of most clinical cavities and the proposed location for measuring bond strength of composites so that no pulp exposure occurred in the preparation site. The final preparation of sample surface was done by 600 grit silicon carbide paper. Afterwards, the teeth were embedded in an acrylic resin up to the preparation site.

The samples were randomly divided to eight groups of ten each. The treatment for the eight groups was as follows:

Group 1: 2-mm-thick P60 composite cured by QTH for 40 sec

Group 2: 5-mm-thick CeramX composite cured by QTH for 40 sec

Group 3: 5-mm-thick P60 composite cured by QTH for 40 sec

Group 4: 2-mm-thick P60 composite cured by LED for 20 sec

Group 5: 2-mm-thick CeramX composite cured by QTH for 40 sec

Group 6: 2-mm-thick CeramX composite cured by LED for 20 sec

Group 7: 5-mm-thick CeramX composite cured by LED for 20 sec

Group 8: 5-mm-thick P60 composite cured by LED for 20 sec

Two metal molds were made (2.5 mm in diameter and 2 or 5 mm in height) in order to hold a certain volume of composite on the prepared teeth. However, two same-size alternative handmade polyvinyl siloxane molds were prepared and used because the composite samples were not adequately cured in the depth of 5 mm in metallic molds so that the part in contact with teeth was too soft to make a bond with the tooth structure.

Each sample was etched for 15 sec with 37% of phosphoric acid and rinsed for 20 sec with water.

After placing molds on the surface of tooth (completely on dentin), bonding was used on the dentin according to the manufacturer's instruction and it was cured from inside the mold.

Then, the composite was placed on the dentin inside the mold and was cured according to the following figure. The composites used in this experiment were of Ceram-X and P60 types, which were cured in bulk after being placed in the metal mold. To simulate oral conditions, the samples were kept in water for 90 days.

In the groups in which LED device was used, curing time was 20 sec (according to the manufacturer's instruction) and, in QTH samples, it was 40 sec.

Then, each sample was placed in universal testing machine (Zwick Roell-Z250, Germany) under shear forces at speed of 1 mm per min and shear bond strength was recorded in MPa. Data were analyzed using 3-way ANOVA to evaluate interaction of the variables.

Results

Minimum, maximum, and mean ± standard deviation of shear bonding strength of composites to dentin was recorded in MPa and analyzed using one-way ANOVA in experimental groups, as shown in Table 1.

Table 1. Minimum, maximum and mean of shear bonding strength of composite to dentin

Studied groups	Min	Max	Mean	SD
1	20/20	44/90	28/6	7/36
2	8/22	21/90	15/38	4/49
3	11/70	30/10	17/79	5/53
4	18/60	49/90	31/75	11/43
5	10/50	33/40	19/58	7/64
6	15/20	44/10	25/61	8/92
7	10/00	27/70	15/34	5/53
8	10/20	22/40	16/57	4/23

The results of three-way ANOVA test did not show any interaction between the variables of composite type, thickness and curing method.

Investigating the main effects, it was found that different composite thicknesses made significant changes in bond strength of the groups. In this study, mean bond strength of P60 and Ceram X composites were 21.3±7.06 and 18.60±6.69, respectively, which indicated a significant different (p=0.025).

Moreover, mean of bond strength in the 2- and 5-mm thicknesses were 23.74±7.05 and 16.84±4.78, respectively, which showed a significant difference.

Discussion

Development of new technology for photo-activation of dental composites and claim of some composite manufacturers for bulk curing of composites has attracted attention of many researchers. These claims have yet to be proven. In addition, properties of the cured composites should be evaluated before being conventionally used in the treatment, [9].

In this study, both P60 and CeramX composites had higher filler content compared with common types of composites in the market. It has been proven that composites with more filler content (hybrid and nanofilled composites) have better mechanical properties [11,12].

In this study, shear strength of composites at depth of 5 mm was considerably less than that in the depth of 2 mm. Conversion degree of monomers in light-cured composites differed in various parts of the composite bulk and depended on the distance from the light source. It can be attributed to the fact that conversion process of methacrylate molecules needs light energy to be activated and is also affected by the filler content. With the increase in filler content and size, light scatters and reflects more, which leads to deeper light penetration. This can explain more conversion degree and higher hardness of packable composites with larger filler sizes. With increased composite thickness, the amount of light transmission decreases. In some previous studies, the rate of hardness and conversion degree decreased by increasing composite thickness [11].

Bond strength in the thichness of 5 mm was considerably less than that in 2 mm, which showed that the depth of composite was not properly cured. Previous studies in this field have confirmed that hardness and conversion degree of composites are significantly reduced in thicknesses of more than 2 mm [13].

The amount of light energy which the composite receives in each sample is equal to duration of curing multiplied by light intensity of the unit. Accordingly, each cured sample by LED received 20×900=18000 mw/cm² of light energy and each cured samples by QTH received 40×600=24000 mw/cm² of light energy and this amount of energy was more than the minimum recommendation (17000 mw/cm²) for proper curing. The results showed that a large amount of energy was required for polymerization of the samples at depth of 5 mm [13]; 2 and 5 mm metal molds do not allow light penetration from the surrounding composite and light strikes the sample composite through the composite surface. If a white mold is used, curing depth significantly increases because it allows light to penetrate from sides in comparison with dark steel molds. To maximize light penetration into composites, lighter colors can be used [13].

Manhart et al. (2001) compared different types of composites and concluded that packable composites have better mechanical properties than other types, but they recommended further investigations [14].

In the study by Abe et al. (2001), P60 composite showed acceptable results in terms of mechanical properties [15].

The results of the present study confirmed better curing of QTH in comparison with LED, which was not statistically significant. In QTH unit, to produce blue light, the lamp should be heated to a very high temperature, which leads to release of heat at its tip. The heat transfer itself accounts for determining the curing depth obtained in the composite because it can improve movement of monomers and enhance their conversion into polymer. Another factor affecting curing depth is the total amount of energy that reaches the composite, as mentioned in the previous section [16]. If the curing time is shorter, less light will reach the depth of composite and the light needed for polymerization will be absorbed or scattered by composite surface layers. This problem can justify reduced strength of cured samples with LED [2]. Considering that LED curing time was half of QTH, reduced strength of samples was not statistically significant. Acceptable performance of LED unit can be attributed to narrow spectrum and 470 nm peak wavelength, which corresponded to ideal wavelength of starting camphorquinone [16].

Queiroz et al. (2009) conducted a study in which QTH and LED units showed acceptable performance [16].

LEDs used in dentistry produce a narrow range of blue light with wavelength of 400-500 nm.

Most advances of technology have provided the possibility of creating high power LEDs (HP) which claim for reduced curing time. To achieve this reduction, new LEDs have external intensity of up to 1000 mw/cm². Since all external spectrums of LED focus on the range of blue light wavelength, more effective curing has been caused which reduces curing time compared with the first generation of LED and QTH devices and they are comparable to high-intensity halogen lamps [17].

In general, LED and QTH units with similar light intensity create similar curing depth and it is necessary to do further investigation in order to prove LED efficacy in curing composites. Although it can be said that 5 mm depth of composites is finally polymerized, the strength of initial weak bond is not enough to resist against polymerization shrinkage, which can increase microleakage and cytotoxicity [3].

Conclusion

1.Shear bond strength of P60 and CeramX composites in 5 mm thickness was less than 2 mm.

2.Two types of studied curing units did not create a significant difference in shear bond strength.

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