Available online at www.elixirpublishers.com (Elixir International Journal)

Condensed Matter Physics

Elixir Condensed Matter Physics 180 (2023) 56994 - 56997

ISSN: 2229-712X

Effect of Curing Distance on Depth of Cure of Composite Resin Using Different Light Curing Units of Different Intensities

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ARTICLE INFO

Article history:
Received: 8 June 2023;
Received in revised form: 21 July 2023;
Accepted: 30 July 2023;

Keywords
Restorative Material,
Polymerisation Characteristics,
Resin composite.

ABSTRACT

The aim of this study is to determine the effect of altering the distance between the light source and the surface of the restorative material (DLR) on the depth of composite cure with a range of low to high light intensity with different types of light cure units. This in vitro study compared the depth of cure obtained with five quartz tungsten halogen and light-emitting diode curing units at different exposure times and light tip-resin composite distances. Resin composite specimens (Tetric Ceram, A3; diameter 4 mm, height 6 mm) were exposed from 1-, 2-, 3-, 4-, and 5- mm distance. The depth of cure determined using the scrape test ISO 4049. Light intensity was also measured at each separation distance for each light. The depth of cure was generally found to decrease as the separation distance increased for all lights at the various cure times. However, the effect of increasing the separation distance was less than anticipated. The depth of cure was also related to the light output. Depth of composite cure was directly related to intensity and duration of light exposure and inversely related to distance of the light source from the surface for halogen and plasma lights. However, the effect of increasing the separation distance up to 15 mm was less than expected. Altering the separation distance in order to modify the polymerisation characteristics is unlikely to be effective.

Introduction

Light-cured resin composites have become increasingly popular since their introduction in the 1970s, allowing dental restorations to be more conservative and aesthetic.The composite degree of cure is affected by factors such as: a) Power density of the curing units, b) The exposure time, c) The resin shade and d) The filler size and the loading level. Light intensity decreases with increasing the distance between the light source and the surface of the restorative material (DLR) and some authors refer to an inverse square law relationship. Knowing the depth of cure of a particular shade of light-activated composite material would guide them in regard to the thickness of a composite layer that could be adequately cured clinically and provide them with a valuable baseline information about the specific depth of cure of different light-activated composite materials used by dentists. The aim of this study was to determine the effect of altering the DLR on the depth of composite cure with a range of low to high light intensity with different types of light cure units.

Materials and Method

Three halogen light-curing units (A: Optilux, Kerr; B: Heliolux VL, Vivadent; C: Visiolux, 3M) and two LED units (D: Radii Plus, SDI; E: Coltolux LED, Coltene Whaledent) were selected to provide lights of low to high output.

Specimen Preparation

Total 250 specimens were made with resin composite (Tetric Ceram, A3; diameter 4 mm, height 5mm). Each composite resin specimen was placed into a 5 mm high and 4 mm diameter Teflon mold with a centered hollow area as shown in the figures 1 and 2.

Fabrication of composite samples: (Fig. 1 & 2)

These specimens were divided into 5 groups (n=50). Each group were further divided into 5 sub-groups (n=10) on the basis of curing distance used (1mm, 2mm, 3mm, 4mm and 5 mm).

Curing regime

The specimens were exposed from 1mm, 2mm, 3mm, 4mm and 5 mm distance.

A Demetron 100 radiometer (Demetron Research Corp, USA) and SDI radiometer was used to determine the light intensity from the light curing units.

Immediately following light curing of each specimen, depth of cure of the composite was assessed, by one operator, by means of a scraping technique according to ISO 4049.

ISO 4049 scraping technique

This involved scraping off the uncured bottom surface with a plastic spatula. The smallest distance between the surface and the base of the remaining cured composite was measured using a digital vernier caliper, followed by dividing the average length by 2 to obtain the result.

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Figure 3

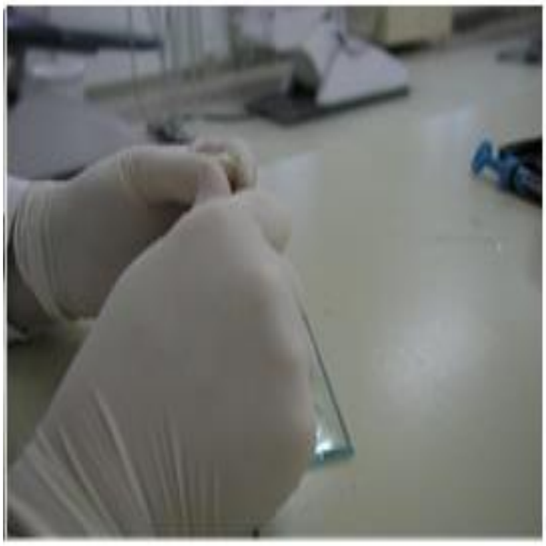

Figure 4

Figure 5

Results

The visible light (VL) output was determined before and after each experiment to ensure that the light intensity was not varying during the experimental procedures. Five readings were determined, and a mean value calculated, before and five readings after each of the experiments. These mean values of light output ranged before and after each experiment as indicated by the following results: light A = 416-420 mW/cm^2, light B = 175-178 mW/cm^2, light C = 79-83 mW/cm^2, light D = 1920 mW/cm^2 and light E = 845-880 mW/cm^2. The differences in the mean values of light output for each light source over the duration of the experiment (data not presented) were not significant (ANOVA, $P>0.05$). This indicated that each light unit continued to function at a constant level throughout the experiment, although lights B and C were a level below that considered to be clinically effective. The results for VL intensity from the curing lights at different DLR, determined using a radiometer, are shown in Table 1.

Table 1. Mean visible light radiometer readings (mW/cm^2) for the halogen (A-C), PAC (D) and LED curing lights (E and F) at the different separation distances between radiometer and light tip (n=l 0)

Separation distance (mm)								
	0	**1**	**2**	**3**	**4**	**5**	**7**	**10**
Unit A	420	376	336	284	234	194	-	88
Unit B	196	194	190	180	175	170	-	95
Unit C	82	72	68	64	52	40	-	26
Unit D	1208	1308	1218	1076	984	884	-	556
Unit E	1920	1846	1706	1485	1299	1045	645	174

Statistical analysis (ANOVA) indicated that the effect of increased DLR on light intensity was statistically significant. The VL intensity decreased with increased DLR for each light. For the two LED lights, there was no significant difference between 0 mm and 5 mm separation.

The depths of cure, calculated by measuring the thickness of cured composite remaining according to the ISO 4049 test at each separation and for each light source are included in Table 2. The light unit with the lowest VL output had the least depth of cure. Similarly, the light with the greatest VL output had the greatest depth of cure. Depth of cure decreased as DLR increased, with a greater depth of polymerisation at 60 seconds than 20 seconds. The mean increase in cure depth at 60 seconds compared with 20 seconds for the three halogen lights was calculated for each light at each separation distance and was determined to be 1.41±0.07 mm. The results obtained using two LED light-curing units (Table 2) were similar to those obtained with the halogen lights, with the depth of cure reducing at an increased DLR.

Table 2.

POlymerisation depth date in distance (mm)						
	0	**1**	**2**	**3**	**4**	**5**
20s unit A	3.18	2.80	2.51	2.52	2.45	2.41
20s unit B	2.89	2.66	2.47	2.43	2.41	2.35
20s unit C	1.81	1.77	1.57	1.53	1.51	1.51
60s unit A	4.20	3.02	3.69	3.56	3.52	3.46
60s unit B	3.91	3.02	3.77	3.64	3.52	3.45
60s unit C	2.39	2.25	2.22	2.22	2.16	2.03
3s unit D	4.40	4.40	4.14	4.04	3.94	3.92
20s unit E	5.11	-	-	-	-	5.32

Discussion

Five different light-curing units, all in clinical use, were selected for the depth-of-cure study. This was to avoid problems inherent in filtration or other modifications of a single light in order to reduce light output artificially, the method employed by Fowler et al. (1994)[12], which may not mimic the clinical condition.

Depth of cure: The ISO depth of cure (scraping) test used to determine depth of cure required minimal instrumentation and can be performed easily in a dental office. Using the curing light in their offices, dentists can readily adopt the ISO method to establish the depth of cure of various composite materials used in their practices. Once a baseline value is established, the dentist can use this method to check the depth of cure periodically to verify the performance of the resin-based composite and the curing light. Although commercial light meters are available, they measure only the intensity of curing light. Resin-based composites can vary in composition, color and translucency, and curing-light intensity alone does not ensure adequate depth of cure.

By using the ISO method to determine the depth of cure for a specific curing light and resin-based composite, dentists can obtain valuable information that can be applied clinically. The ISO defined depth of cure as 50% of the length of the composite specimen after the uncured material is removed with a plastic spatula. Although some researchers have used the total remaining length as the depth of cure after uncured material is removed, other studies have shown that, the hardness of the cured composite decreased significantly from the top of the specimen toward the bottom. If the total remaining length was used as the depth of cure, under polymerization likely would occur and clinical performance could be compromised.ISO adopted a more conservative standard, defining the depth of cure as 50% of the remaining length. It was suggested that the depth of cure be defined as 55% of the remaining length of the scraped specimen.

DeWald and Ferracane compared the scraped values with those obtained with double-bond conversion, hardness tests and translucency-changes as methods to determine depth of cure. Fan et al.[10] analyzed their data and concluded that, 50% of the scraped length results in similar or more conservative depth-of-cure values than those determined by the extent of double-bond conversion using infrared spectrometry or hardness. Therefore, the ISO method should ensure adequate polymerization of most resin-based composites.

The extent of polymerization is reduced at greater depth below the material's surface because of the lower intensities of light penetrating to this depth. Depth of cure is affected by the size of the incorporated fillers. The filler particles in the resin-based composites scatter light. This scattering effect is increased as the particle size of the fillers in the composite approaches the wavelength of the activating light and will reduce the amount of light that is transmitted through the composite.

Curing distance: The VL output from all of the curing lights remained constant throughout the experiment. The observed differences in depth of cure with increasing DLR could not, therefore, be explained by variation in intensity of output caused by variation in mains voltage, deterioration of the bulbs, reflectors, fibre optics, or condition of the tips of the light sources. The VL intensity and depth of cure decreased as DLR increased for all lights, in accordance with previous studies.

In this study, each curing system and composite type significantly were affecting depth of cure, the effect of composite composition on the depth of cure is very obvious and this finding is in agreement with the finding of De Backer and Dermaut who found that the most important factors affecting the polymerization depth are the composition and the physical properties of the composite resins and not the energy density. While Spectrum dental composite showed the lowest values of depth of cure.Depth of cure of light activated resin-based composites is a function of the material's filler composition and resin chemistry, its shade and translucency, the intensity of the light source, and the length of the radiation exposure. Light output decreased as the Distance between the light source and the surface of the restorative material (DLR) increased, and depth of cure also decreased as the DLR increased in most tests in the current study. Past authors[11] have described a relation between the depth of cure at increasing DLR to log10 of the mean light intensity and this is confirmed in the present study for VL output. Hansen and Asmussen (1997)[6,11] showed that depth of cure decreased modestly and in a linear manner with increasing distance, and Rueggeberg and Jordan (1993)[24] showed that light intensity did not obey the inverse square law over distances 0-10 mm, which is in agreement with the results of the present study. Abate et al (2001)[25] showed that the surface hardness of composite resin did not differ significantly when the DLR varied over 0- 15 mm whereas Leloup et al (2002)[10] showed a significant decrease in depth of cure when the DLR was greater than 20 mm.

The light of low output (unit C in this study, 80 mW/cm2) was found to be capable of curing, after 20 seconds, a 1.8 mm thickness of composite resin at zero separation from the composite material. However, only approximately 50% of this thickness can be considered fully cured. Increasing the separation reduced the depth of cure such that, at 10 mm separation, this light was only capable of fully curing some 0.7 mm of composite (1.4 mm with the ISO 4049 test). Increasing the cure time from 20 to 60 seconds increased the mean depths of cure by a factor of approximately 1.4. This is in agreement with previous observations for zero separation of the light source tip and composite material.

Conclusion

In the current study, although the depth of composite cure decreased with increasing separation distance of the restoration from the light source, the reduction in depth of cure at the extreme (15 mm) separation distance was less than expected. Increasing the separation distance between curing light tip and polymerisable material is not a reliable method for reducing the light intensity as part of a modified curing regimen because the effect of separation distance was less than expected. LED curing lights did not perform differently from the other types of curing light as separation distance increased.

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