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Original research

Comparison of Depth of Cure at Three LED Light Distances with Three Colors of Composite Resin

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Abstract

Introduction: If the resin does not receive enough photons at the appropriate wavelengths, the degree of polymerization will be inadequate. There may be greater wear and microleakage, less hardness, and decreased elastic modulus, which can cause pigmentation, postoperative sensitivity, and caries recurrence. **Objective:** To compare the depth of cure (DC) of the composite resin in shades A1, A2, and A3 at 0 mm, 5 mm, and 10 mm distance with light emitted by diodes (LED). **Materials and methods:** 180 samples in 9 groups (n=20). Brilliant™ NG, Coltene composite resin was used. A1, A2, and A3 at 0 mm (control group), 5 mm, and 10 mm distance of light curing with LED lamp (3M Elipar Deep Cure) for 20 s according to the manufacturer's instructions. Following the test method of the UNE-EN-ISO 4049-2019 standard, the non-polymerized material was removed with a plastic spatula. DC (mm) was obtained with a micrometer with an accuracy of ±0.1mm. **Results:** The depth of cure at a distance of 0 mm of the A1 composite was greater (2.89 mm) compared to the A2 and A3 groups with 2.86 and 2.83 mm respectively, (ANOVA $p<0.001$). At a distance of 5 mm, the DC of the composite resin A1 was 2.77mm, while with shade A2 it was 2.47mm and A3 was 2.37mm (ANOVA $p<0.001$. At a distance of 10 mm, the resin A1 obtained a PC of 2.65mm compared to 2.37mm in A2 and 2.23mm in A3 (ANOVA $p<0.001$). **Conclusions:** As the distance between the light source and the resin increases, the DC is affected. Therefore, inadvertently moving the light source away from the composite negatively affects curing, reducing the quality and longevity of the material in the mouth.

Keywords: Depth of cure, resin, cure distance, UNE-EN-ISO Standard 4049-2019.

INTRODUCTION

Composite resin has become a material of first choice for direct dental restorations due to its mechanical and esthetic properties. The clinical success of composite resin restorations can be affected by inadequate light curing of the material, whereby the lower part of the composite resin will receive less amount of light, having a lower degree of conversion (43-75%), resulting in lower mechanical properties, higher sorption, and higher color change[1]. The ideal properties that composite resins should possess are reduced shrinkage percentage and good workability that allows them to reach all preparation areas without creating voids[2].

It is widely known that factors such as the irradiance emitted by the light curing units and the exposure time supplied to the material play an important role in the quality of light curing and the subsequent success of composite resin restorations. It has been considered that 16 J/cm^2 having between 700 and 800 mW/cm^2 is the adequate energy to cure increments of up to 2 mm of composite resin and exposure times of about 20 s to achieve an acceptable depth of cure[3]. UNE-EN-ISO 4049-2019 specifies the depth of cure requirements for type 2 polymer-based restorative materials (those activated by external energy) i.e. light cured through blue light, shall not be less than 2.0 mm for opaque materials, less than 1.5 mm for all other colors, or not more than 0.5 mm below the value established by the manufacturer[4].

Light-cured composite resin is widely used as a restorative material, however, a persistent problem is that all parts of the material must be exposed to a sufficient amount of light and that the light must be constant and homogeneous to achieve complete polymerization, which

can be measured by the degree of conversion, which on average ranges from 43% to 75%, or through the depth of cure thus depending on the intensity of light emitted by the light-curing unit[5,6]. During the polymerization process of the composite resin, most of the monomer must be converted into polymers, through the rupture of C=C double bonds, becoming C-C single bonds. However, this polymerization reaction can be affected by several factors, some directly related to the composite resin (such as collision between polymer chains, cross-linking of chains) and others related to the characteristics of the light-curing lamps such as low irradiance (<800 mW/cm^2), low exposure time, incorrect activation of photoinitiators, which would cause the carbon-carbon double bond not to be broken correctly, thus reducing the mechanical properties and producing postoperative pain[7-9].

To produce the light curing phenomenon, a light source is necessary, which acts as an activator of the photoinitiators present in the composite resin[10]. Among the main photoinitiators used in composite resins are: camphorquinone, whose activation range oscillates between 400-500 nm; 1 phenyl-1,2 propanedione, which can be activated between 360-480 nm, and lucerin, which can be activated between 350-430 nm[11]. Therefore, the light curing lamps used should be per the wavelength range required by each photoinitiator[10,12]. The light curing of composite resin with darker shades will be affected because the pigments present in the composite resin absorb or impede the passage of light, thus affecting the depth of cure of the material and requiring longer exposure times[13,14]. Therefore, this work aimed to compare the depth of cure of composite resins with A1, A2, and A3 shades at 0 mm, 5 mm, and 10 mm distance with light emitted by diodes (LED).

MATERIAL AND METHODS

The depth of cure (DC) was assessed according to the UNE-EN-ISO 4049-2019[4] standard. The irradiance of the LED lamp (3M Elipar Deep Cure) was measured with a digital radiometer Bluephase Meter II (Ivoclar Vivadent), which was 1470 mW/cm^2. A total of 180 samples were prepared and divided into 9 groups (20 for each group), shade A1 corresponds to groups G1, G4, and G7, shade A2 corresponds to groups G2, G5, and G8 and shade A3 corresponds to groups G3, G6 and G9 which were subjected to 3 different light-curing distances to carry out the DC test.

Following the specifications of the UNE-EN-ISO 4049-2019 standard, a 20 mm by 20 mm slide of 2 mm thickness was used, on which a transparent tape was placed, and on top of it, the mold of 4 mm in diameter and 6 mm in length (Figure 1), a layer of silicone oil separator was placed on the mold with a microbrush, the mold was filled with Brilliant™ NG Resin (Coltene) taking care that no air bubbles were left, the mold was slightly overfilled and a second transparent tape was placed on top, followed by the second slide, the mold, and the transparent tapes were pressed between the 2 glass slides to displace the excess material, the slide was removed and light cured at a distance of 0 mm in the control group and then at a distance of 5 and 10 mm.

To maintain the distance between the resin surface and the light source, a glass tube with a length of 5 mm (Figure 2.B) and a 10 mm tube, both with a diameter of 6 mm (Figure 2.C), were used. Groups G1, G2, and G3 were light-cured by placing the lamp directly on the surface at a distance of 0 mm (Figure 2.A), considering the control group and following the manufacturer's light-curing recommendations; groups G4, G5 and G6 were light cured at a distance of 5 mm controlled by placing the lamp on the 5 mm long glass tube, and groups G7, G8 and G9 were light cured at a distance of 10 mm by placing the lamp on the glass tube (Figure 2). Each sample was photocured for 20 s following the manufacturer's instructions.

Figure 1. A. Mold on the glass, B. Brilliant™ NG resin (Coltene). C. Placement of the resin on the mold.

Once the light curing process was completed, each sample was removed from the mold and the non-light cured material was removed with a plastic spatula, the length of the sample was measured with a digital micrometer with an accuracy of ±0.1 mm, and the value was divided by two and recorded as the depth of cure (Figure 3).

The data obtained were entered into a database in the SPSS v.24 statistical program, the Shapiro Wilks test was applied to determine the normality of the data and then an ANOVA test was used with a post hoc test for multiple comparisons using the Bonferroni test. The confidence interval was 95%. The test for homogeneity of variances showed that the data complied with a normal distribution (0 mm p=0.08, 5 mm p=0.095, and 10 mm p=0.211).

RESULTS

The results are shown in Table 1 and Graph 1. In the depth of cure at 0 mm, it was observed that the composite resin G1=A1 obtained the highest value of 2.89 mm, compared to groups G2=A2 and G3=A3, with 2.68 and 2.63 mm respectively (ANOVA $p<0.001$, post hoc Bonferroni $p<0.001$).

When the light-curing distance was increased to 5 mm, the same behavior was observed, where A1 composite resin presented the highest depth of cure (2.77 mm) compared to 2.47 and 2.37 mm obtained by the G5=A2 and G6=A3 groups (ANOVA $p<0.001$, post hoc Bonferroni $p<0.001$).

When the composite resin increased at 10mm of light curing distance, again the same trend was observed, the darker the shade of the composite resin the lower the depth of cure, shade A1 obtained 2.65 mm, while the lowest depth was by G9=A3 with 2.23 mm (ANOVA $p<0.001$, post hoc Bonferroni $p<0.001$).

DISCUSSION

In this study, the depth of cure of 3 shades of resin at 3 different distances (0 mm, 5 mm,10 mm) was evaluated, the depth of cure test consisted of preparing specimens according to the

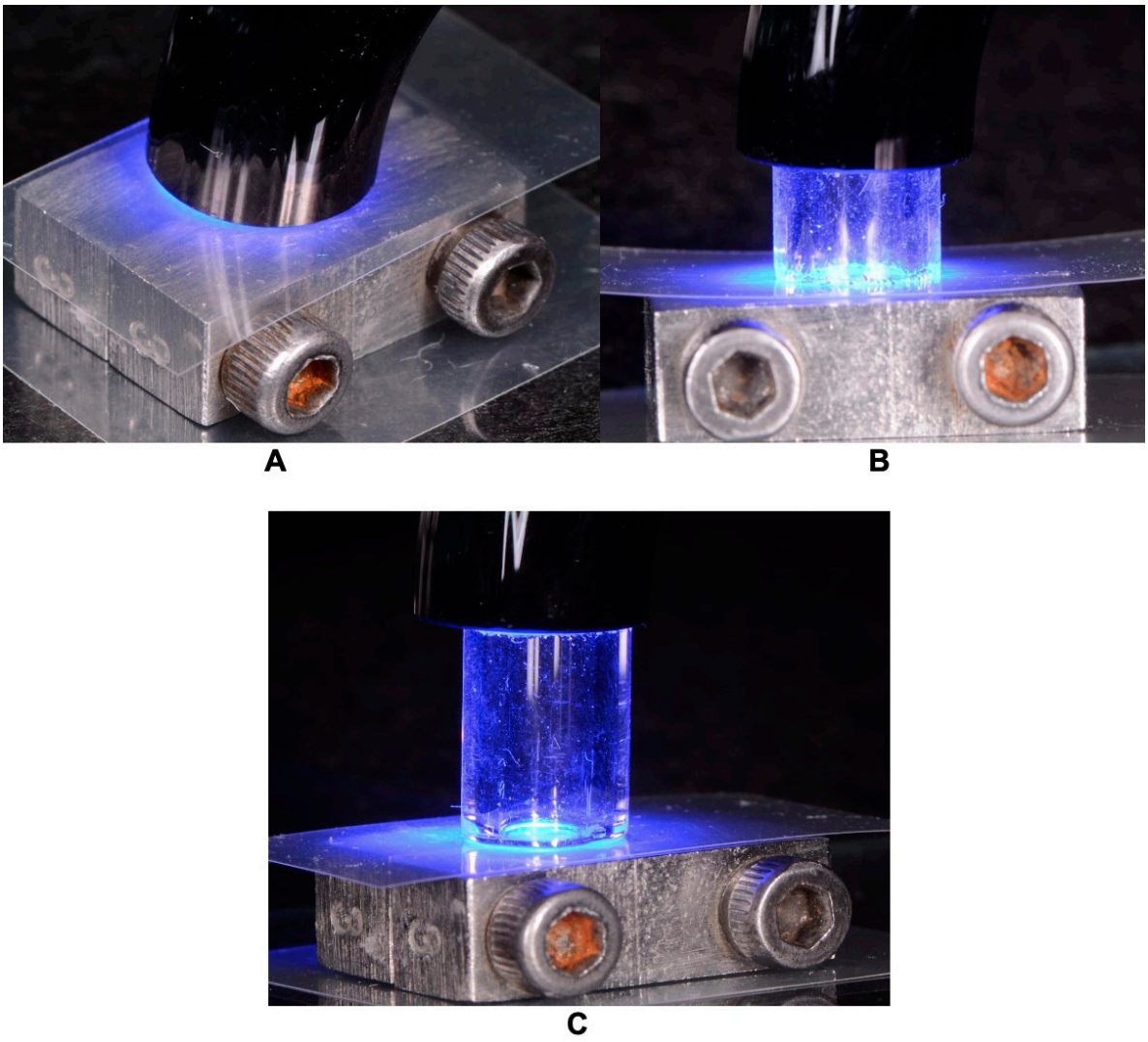
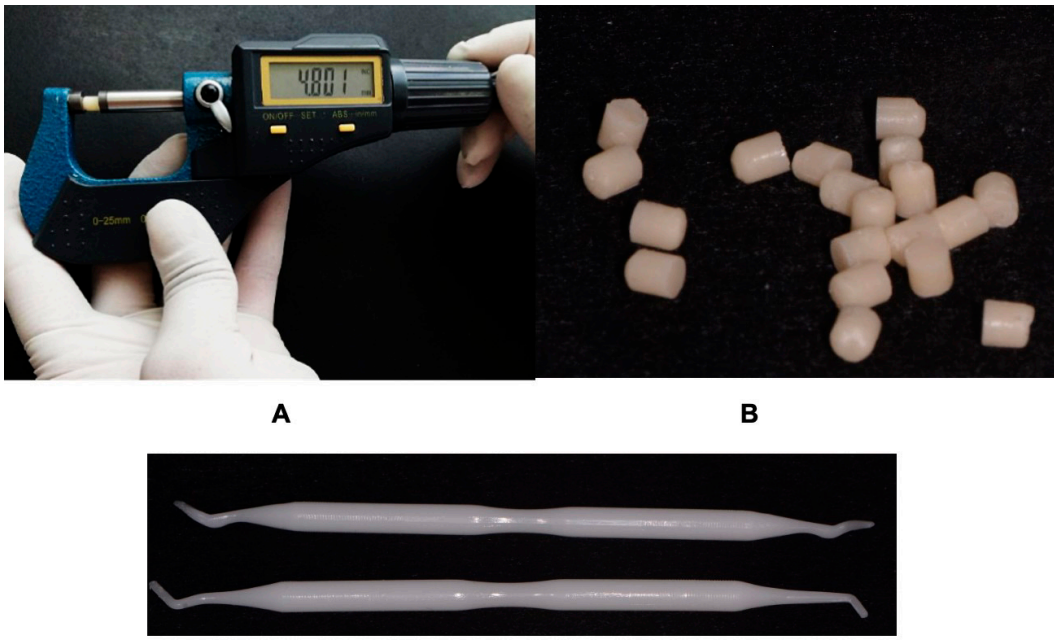


Figure 2. A. Light curing at a distance of 0 mm, B. Light curing at a distance of 5 mm. C. Light curing at a distance of 10 mm.

specifications of the UNE-EN-ISO 4049-2019 standard. Once light-cured, they were removed from the mold and the uncured material was removed with a plastic spatula, with a digital micrometer the cylinder height of the cured material was measured and the value obtained was divided in two. Based on our results we report an indirectly proportional correlation between distance and depth of cure, i.e.: the greater the distance from the light tip to the resin surface, the lower the depth of cure; the smaller the distance from the light tip to the resin surface the greater the depth of cure; likewise a correlation was observed between depth of cure and resin shade, i.e.: the higher the pigmentation (A3) the lower the depth of cure, the lower the pigmentation (A1) the greater the depth of cure.

Ferracane *et al.*[15] determined the depth of cure by measuring the hardness and degree of conversion of composite resins. They found that the lighter shade had a greater depth of cure compared to the darker shades. However, they also suggest that the depth of cure of light-activated composite resins may be less dependent on shade than on other factors, such as translucency. This research agrees with ours in how the depth of cure is affected by resin



A B C

Figure 3. A. Measuring the depth of cure. B. Samples and C. Plastic spatulas to remove uncured resin.

Table 1. Mean and standard deviation.

n=20	0 mm		n=20	5 mm		n=20	10 mm	
Group/Color	**Mean**	**SD**	**Group/Color**	**Mean**	**SD**	**Group/Color**	**Mean**	**SD**
G1=A1	2.89	0.03	G4=A1	2.77	0.05	G7=A1	2.65	0.04
G2=A2	2.68	0.05	G5=A2	2.47	0.02	G8=A2	2.37	0.05
G3=A3	2.63	0.05	G6=A3	2.37	0.03	G9=A3	2.23	0.03

Table footnote: SD: standard deviation. ANOVA p<0.001, post hoc Bonferroni test p<0.01, statistical differences were found between the three groups when compared by distance, n=20. Equal lowercase letters indicate no statistical difference.

Chart 1. Average depth of cure at a distance of 0 mm, 5 mm and 10 mm, n=20.

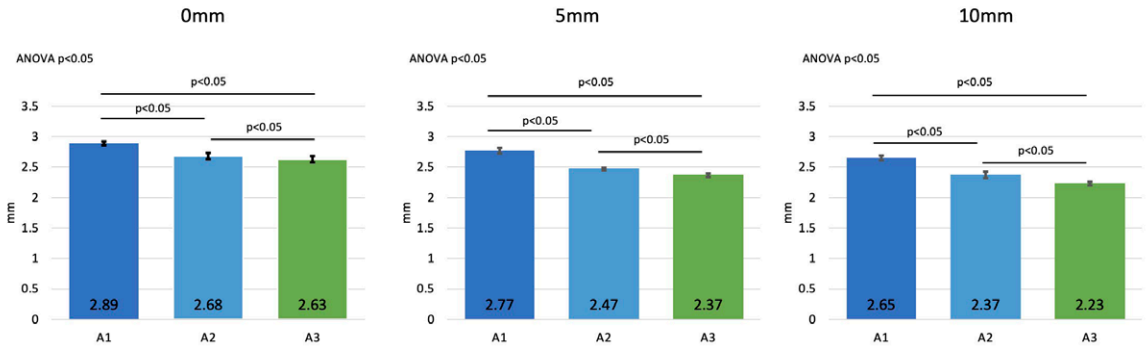


Chart footer: ANOVA p<0.05, pos hoc Bonferroni test p<0.05, statistically significant differences were observed for each color.

shade. It should be noted that their methodology and materials were different from those used in our research.

Shortall[16] mentions that the depth of cure will be directly influenced by the shade, translucency, and opacity of the resin, giving the clinical recommendation that the more pigmented and opaquer the resin, the longer light application time will be necessary. We agree that the depth of cure is decreased the darker the shade of the resin color.

AlQahtani *et al*.[17] mention that the greater the depth, the fewer photons can pass through the resin material, which means a lower light curing capacity, which we agree with, since they coincide with our results despite using a different methodology.

CONCLUSION

The depth of cure decreases as the distance between the light source and the surface of the composite resin increases. Therefore, inadvertently moving the light source away from the composite resins negatively affects their cure by reducing the quality and durability of the material in the mouth. It was observed that the depth of cure decreases as the shade of the composite resin becomes darker (A3) and increases as the shade becomes lighter (A1).

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