

Distance and protective barrier effects on the composite resin degree of conversion

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Abstract

Context: The food wrap films are used to cover the tip of curing light units in order to avoid contamination and prevent damage to the light guide. However, their effects on resin polymerization are not fully known. **Aims:** We investigated the effects on restoration efficiency of a food wrap protective barrier used on the tip of curing light units. **Materials and Methods:** For each treatment, five replications were performed, a total of 60 bovine incisor. The degree of conversion (%DC) of restorations with the composite resin Opallis EA2 was evaluated using 3 curing light devices (Optilux 501, Optilight and Ultra LED) and 2 curing distances (0 and 5 mm). The composite resin was tested for restoration of cavities in bovine crowns. %DC values were measured by the Fourier transform infrared spectroscopy-attenuated total reflectance technique. **Statistical Analysis Used:** The data were analyzed using 3-way ANOVA and Tukey's test. **Results:** Use of the protective film lowered %DC ($F = 4.13$; $P = 0.05$), and the effects of curing distance were associated to the curing light device ($F = 3.61$; $P = 0.03$). **Conclusions:** The distance from the light curing tip and use of a translucent protective barrier on the light-cure device can both impair composite resin %DC.

Keywords: Composite resin, dental curing lights, dental infection controls, Fourier transform infrared spectroscopy, polymerization

Introduction

For Bis-GMA composites, the degree of conversion (%DC) ranges from 50% to 70% is satisfactory in providing chemical stability for restoration.^[1] One of the main factors affecting polymerization efficiency is the light-curing units (LCUs) used. The intensity of LCU light (power density) is determined by the features of the curing unit. The distance between the light source and the increment,^[2] duration of light exposure, and obstruction of the tips with resin^[3] are additional factors that interfere in resin polymerization.^[4,5] Another element that may affect polymerization efficiency is the protective barrier use to completely envelop the light tip.^[6] Although, using a protective barrier is recommended

by the National Center for Chronic Disease Prevention and Health Promotion (CDC)^[7] for semi-critical instruments as curing light tips, they may attenuate light transmission and impair polymerization.^[3]

This study was tests if the use a food wrap protective barrier on the tip of quartz-tungsten halogen and light-emitting diode (LED) curing light units compromises %DC of a microhybrid composite resin and that this effect increases with curing distances. The distances tested were 0 and 5 mm.

Materials and Methods

General design

The experiment was developed applying a $2 \times 2 \times 3$ factorial design (2 tip protection levels, 2 curing distances, 3 types of curing units/irradiance), with 5 replicates. Cavities were prepared in bovine crowns and restored under the tested conditions. Irradiance of the different LCUs tested was also measured. The resin %DC obtained by the different treatments was determined using the Fourier transform infrared spectroscopy-attenuated total reflectance (FTIR-ATR).

Cavity preparation

Cylindrical class I cavities (5 mm diameter and 1.4 mm deep) were prepared on the vestibular surface of 60 bovine incisor crowns embedded in polystyrene resin. Divergent walls were prepared with a #4054 diamond-tipped wheel bur and a #716 diamond-tipped flat-ended and tapered bur (KG Sorensen, Barueri, SP, Brazil), coupled to a specialized device for cavity preparation (ELQUIP, São Carlos, SP, Brazil).

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Irradiance determination

The curing lights tested consisted of an Optilux 501 halogen light (KERR, Washington DC, USA), Optilight LED curing light (GNATUS, Ribeirão Preto, SP, Brazil) and Ultra LED® LED light (DABI ATLANTE, Ribeirão Preto, SP, Brazil). A power meter (Ophir Optronics, Har-Hotzvim, Jerusalem, Israel) was employed to measure the luminous intensity of the devices. Irradiance was calculated based on the values obtained, using the following formula:

$$\text{Irradiance (mW/cm}^2\text{)} = \frac{\text{Potency of the curing unit (mW)}}{\text{Tip area (cm}^2\text{)}}$$

A total of 10 irradiance measurements were taken from each curing unit to estimate mean irradiance [Table 1].

Restoration of the cavities

The microhybrid composite resin used for restorations was Opallis, color EA2 (FGM Ind. Com., Joinville, SC, Brazil; batch # 090109), based on Bis-GMA, Bis-EMA, TEGDMA, camphoroquinone, co-initiator, silane, barium-aluminum-silicate glass particles, pigments, and silica. It contains approximately 57-58% filler particles, with a size of 0.5 μm .

The composite was inserted into a single increment and smoothed with a polyester strip. A cover glass that provided 500 g load was placed onto the composite maintained for 30 s [Figure 1a] and then removed.

The composite resin restoration was cured for 40 s at 0 mm [Figure 1b], with the light tip in direct contact with the polyester tape, or at 5.0 mm distance. To standardize this distance, curing was performed through a spacer, with a central hole 5.0 mm wide and 5.0 mm thick. Specimens were stored in an incubator at 37°C for 24 h and the palatal crown surfaces were then ground toward the restoration with a #1016 diamond tipped bur (KG Sorensen, Barueri, SP, Brazil). Next, the restoration was removed from the cavity using a round-tipped instrument, and analyzed.

Conversion degree determination

The measurements of the top were recorded in absorbance by a Spectrum 100 FTIR Spectrometer (PerkinElmer Inc., Waltham, MA, USA), operating with 16 spectrum scans and 4 cm^{-1} resolution. The %DC was calculated using a baseline technique based on band ratios of 1638 cm^{-1} (aliphatic carbon-to-carbon double bond) and 1608 cm^{-1} (aromatic component group) as an internal standard between the polymerized and un polymerized samples.

Statistical analysis was performed using 3-way ANOVA (tip protection levels \times curing distances \times types of curing units). Tukey's test was applied for multiple comparisons and Mann-Whitney U test for pairwise comparison of significant results. A statistical significance level of 5% was adopted.

Table 1: Mean irradiance (mW cm^2) produced by the light curing devices as a function of curing distance (0 and 5 mm) and use of a protective film on the tip of the curing unit

Curing light unit	Manufacturer	Distance (mm)	Mean irradiance (mW cm^2)	
			Protective film	
			No	Yes
Optilux 501	KERR, Washington DC, USA	0	514.0	506.0
		5	505.0	490.0
Optilight	GNATUS, Ribeirão Preto, SP, Brazil	0	485.7	469.0
		5	483.0	463.0
Ultra LED	DABI ATLANTE, Ribeirão Preto, SP, Brazil	0	472.3	455.0
		5	469.0	450.0

LED: Light-emitting diode

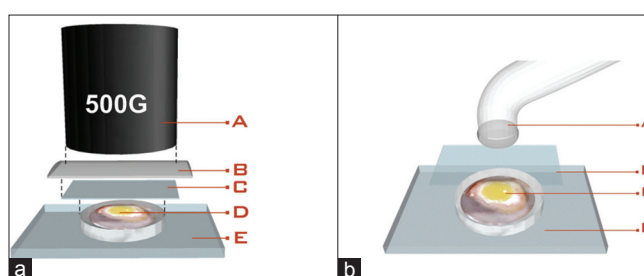


Figure 1: Restoration protocol (a) A – Load; B – Cover glass; C – Polyester strip; D – Resin restoration; E – Glass plate. Photo-activation protocol at 0 mm distance; (b) A – Curing unit; B – Polyester strip; C – Resin restoration; D – Glass plate

Results

Comparing the curing units, the Optilux 501 exhibited the highest irradiance and the ultra LED the lowest [Table 1]. Light emission was up to 4% lower when the polyvinyl chloride (PVC) protective film was used on the tip of the curing unit.

The PVC protective film affected the %DC of the restorations [$P = 0.048$; Table 2]. For all experimental conditions, the samples light-cured with protective film showed a smaller %DC than those light cured without protective film. There was also a significant interaction between curing device and curing distance ($P = 0.035$). For a curing distance of 5 mm, %DC was lower than at 0 mm when using the ultra LED curing unit [Table 2].

Discussion

The DC of monomers in a resin composite into polymers corresponds to the extent (percentage) to which unsaturated bonds are converted into saturated bonds. High %DC values produce good physical properties, namely reduced solubility, higher dimensional stability, and weaker staining.^[1,4,8] On the other hand, inadequate curing maintains unconverted double

Table 2: Mean and standard deviation of the degree of conversion values of resin composite restorations

Curing light	Distance (mm)	Protective film		Pooled Mean (Yes+No)
		No	Yes	
Optilux 501	0	65.68±7.25	63.34±2.76	64.51±5.32
	5	63.88±3.37	62.47±4.55	
	0 x 5			
Optilight	0	61.83±4.92	60.61±6.17	61.22±5.30
	5	66.47±2.41	58.62±6.74	
	0 x 5			
Ultra LED	0	66.14±1.71	65.35±4.97	65.74±3.53
	5	59.82±3.85	58.76±3.39	
	0 x 5			
Source				
Light type (L)	F=0.923049; P=0.404242 (NS)			
Distance (D)	F=3.210688; P=0.079464 (NS)			
Protective film (F)	F=4.131919; P=0.047633**			
L×D	F=3.613298; P=0.034533**			
L×F	F=0.80977; P=0.450946 (NS)			
D×F	F=0.688; P=0.410952 (NS)			
L×D×F	F=0.95522; P=0.391919 (NS)			

*Difference between the curing distances (Mann Whitney U test); **Significant at $P < 0.05$; NS: Non-significant; LED: Light-emitting diode

bonds, making the resin more susceptible to degradation by premature breakdown at the tooth-restoration interface and dimensional instability as well as decreasing color and staining stability.^[8] Inadequately polymerized resin may compromise composite biocompatibility since they can diffuse beyond the dentin and cause an inflammatory reaction in the pulp. Moreover, unconverted monomers leads to post-operative sensitivity,^[5] likely because of methacrylic acid production.^[1]

The intensity of LCUs (power density) is determined by the features of the curing unit, distance from light tip to the composite, exposure time, shade of the resin, filler size,^[9] and type of light guide.^[2] In addition, the polymerization also depends on the spectral output (400-500 nm) and power density/irradiance at minimum (300-400 mW/cm²) of the blue light emitted by the LCUs.^[2]

Although using a protective barrier is recommended by the National Center for Chronic Disease Prevention and Health Promotion (CDC)^[7] for semi-critical instruments as curing light tips, they may attenuate light transmission and impair polymerization.^[3]

Several studies have reported the impact of using PVC barriers^[3,10,11] and how they affect the microhardness of composite resins.^[6,12] However, these studies have not investigated their use in conjunction with different curing distances and effects on irradiance and %DC of the resin. The distance from tip to the composite is an important element

for analysis, given that some cavities do not allow close approximation.^[2]

The present study observe that using a food wrap material, translucent sheets of PVC around the tip of the curing light reduces %DC. Thereby, the curing units tested produced similar polymerization at a 0-mm curing distance, at situations studied. This corroborates other studies which show that power densities from 233 to 800 mW/cm² resulted in similar degree of cure at 0-mm curing distance, with different types and brands of curing units.^[1,9] However, the results show that at a curing distance of 5-mm, composite resin polymerization is compromised when the curing unit has low irradiance potency as was the case with the ultra LED LCU [Table 1]. In addition, the curing quality depends on the type of curing light. The lower irradiance curing light ultra LED [Table 1] produced the smallest %DC values [Table 2]. LED curing units are widely used and comparable to other curing lights,^[1,5] but due to light dispersion they may produce lower polymerization if the distance from the increment is greater than 2-mm.^[13] The effects of curing distance on the %DC values of composite resins are controversial.^[4,5,13] Nevertheless, findings in the present study support the theory that polymerization is affected by curing distance^[9,12] in cases of low irradiance levels, such as those emitted by the ultra LED. Despite its inferior power density performance, restoration quality obtained in this investigation using the ultra LED at a distance of 5 mm was acceptable.

Regardless of the type of curing unit and curing distance applied, PVC film is commonly used for short-term preservation of domestic foods and in Dentistry to envelop and protect the tip of the curing light.^[7] This may decrease light incidence,^[3,6,10-12] although we recorded a reduction lower than 4% [Table 1]. Curing light units generally provide the minimum light intensity recommended (280-300 mW/cm²),^[9] but it may become insufficient with the use of protective barriers on light output.^[6] The degree of interference of barriers on irradiance and polymerization differs according to the type of barrier.^[3,6,10-12]

The use of barriers, the moist surfaces of the mouth (mucosa, tongue, cheek, hand) or external roughness, deviates the linear route of the curing light.^[10] Wrinkles in the film also increase light deviation and energy loss. In order to avoid this effect, protective films in the present study were carefully positioned, without wrinkles, on the curing tips. In the present study, polymerization efficiency and %DC values were likely reduced as a result of light refraction.

It is widely used since it is more practical and affordable than disposable tips or biosafety procedures such as tip sterilization,^[3] which may cause irreversible damage to the device.^[5,10] The food wrap material or the PVC film provides effective, quick, and inexpensive protection against contamination.^[6] It is important to note that dental surgeons often fail to place the PVC film smoothly over the tip, with no wrinkles.^[10] Moreover, they are not used to test light output.^[3,6,11]

It is essential for dental surgeons to know the factors that interfere in polymerization and attempt to attenuate them. For instance, irradiation time can be increased to avoid reduction in photo polymerization when the protective film is used or the tip of the LCU is not in direct contact with restorative material.^[6] Using a protective film on the tip of LCUs and the distance from the light source to the increment are issues that dental practitioners should take into account to avoid functional, esthetic and biological problems provoked by low quality restoration. Physical barriers must be smooth, transparent and capable of clinging to the tip surface to avoid physical damage to light output or reduced polymerization efficiency. In addition, the irradiance potential of the curing unit must be known to determine whether it is high enough to ensure polymerization is not affected by curing distance.

Conclusions

In conclusion, the distance from the light curing tip and use of a translucent protective barrier alter the irradiance on

the light-cure device, which reaches the composite resin, reducing the %DC.

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