



UNIVERSIDADE FEDERAL DE UBERLÂNDIA
FACULDADE DE ODONTOLOGIA



ARTHUR SILVA VIANNA

**EFFECT OF SWEEPING LIGHT CURING UNITS AND REDUCTION OF EXPOSURE
TIME ON DEGREE OF CONVERSION OF RESIN CEMENTS FOR LUTING CERAMIC
VENEERS**

***EFEITO DA VARREDURA DE FONTES DE LUZ E REDUÇÃO NO TEMPO DE
EXPOSIÇÃO NO GRAU DE CONVERSÃO DE CIMENTOS RESINOSOS PARA
CIMENTAÇÃO DE LAMINADOS CERÂMICOS***

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Trabalho de conclusão de curso apresentado a Faculdade de Odontologia da UFU, como requisito parcial para obtenção do título de Graduado em Odontologia.

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Effect of sweeping light curing units and reduction of exposure time on degree of conversion of resin cements for luting ceramic veneers

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Running title: Curing protocols on degree of conversion of resin cements

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Abstract

Objectives: The aim of this study was to evaluate the effect of sweeping monowaves and polywave light curing units and reduction on exposure time on degree of conversion of light-cured resin cements through ceramic veneers.

Methods: Six bovine incisors crowns were cut and included on epoxy resin to simulate six maxillary anterior teeth. An equipment was developed to simulate the sweeping light during light activation of resin cement through ceramic veneers. Two resin cements (Variolink Esthetic LC, Allcem Veneer APS) were applied into the acetate matrix with six cavities with 0.3-mm thickness and 4.0mm in diameter (n=5) simulating the anterior teeth. The 0.5-mm thickness of disilicate ceramic (IPS e.max CAD) were placed over the matrix filled with resin cement. Three light-curing units (LCU) being two monowaves: Elipar Deep Cure (3M Oral Care) and Emitter C (Shuster) and one polywave: Bluephase G2 (Ivoclar) were used to light cure the resin cements through ceramic restorations using three protocols: localized (40 and 10s); sweeping with reduced time (40 and 10s); and sweeping with total time of 6 teeth (240 and 60s). After 24h the degree of conversion (DC, %) was measured on the surface of the resin cement utilizing Fourier transform infrared spectroscopy. Marc resin calibrator (BlueLight Analytics) was used to characterize the LCUs used on this study. Data were submitted to one-way and three-way ANOVA followed by Tukey test ($\alpha=0.05$).

Results: The localized activation resulted in significantly higher DC of the resin cements than sweeping technique using reduced or total time. In general, the exposure time of 40 s resulted in higher DC for both resin cements. No difference on DC values was detected between LCU when localized activation was used. However, sweeping technique using reduced or total time the Emitter C resulted in lower DC than

Bluephase G2 and Elipar Deep Cure. No significant difference on DC values was observed for different teeth when 10 and 40s localized and 240s sweeping for all LCUs. However, when using 10, 40 and 60s sweeping protocols the canines regions resulted in significantly higher DC than all other locations.

Conclusion: The localized activation in each tooth of the resin cement during 40s resulted in more homogeneous DC values. The sweeping the LCU during limited time reduced the DC values, which was not recovered when using the total activation time spent for 6 anterior teeth. Emitter LCU presented lower DC with sweeping technique than Elipar Deep Cure and Bluephase G2.

Clinical Relevance: *The clinicians should be careful with the protocol of photoactivation as stabilization of the LCU since modifying the protocol or reduce the exposure time could led to lower properties of resin cement.*

Keywords: light activation technique, exposure time, light-curing unit, degree of conversion, resin cement, ceramic veneer.

INTRODUCTION

Ceramic veneers have been increasingly performed treatments for esthetics changes conserving more dental structure, in which the ceramic thickness could be between 0.1 to 1-mm.¹ The restorative procedure maintaining the translucence effect known as “contact lens” effect,² restoring the smile esthetics.³ This ceramic restoration is indicated for restoring the color changes, the shape remodeling the tooth morphological alteration, closure diastema, incisal edge prolongation as well as extensive anterior rehabilitation.^{4,5}

Light-cured resin cements have been used for luting ceramic veneers because they present higher bond strength to enamel.⁶ Long clinical working time of the light cured resin cement have improved color stability and the possibility to use try-in systems.⁷ However, luting materials are currently evaluable with different photoinitiators systems such as Norrish type II camphorquinone (CQ),⁸ and Norrish type I photoinitiators called “amine-free” as diphenyl(2,4,6-trimethylbenzoyl) phosphine oxide (TPO). Additionally, the new germanium-based photoinitiator, commercially known as Ivocerin, that reduce the yellowing in long term.^{9,10} These photoinitiators present absorption peak located on different wavelengths, CQ is approximately 470nm and most of absorption is on blue spectrum range. Another photoinitiators are TPO, which extends to violet spectrum range; and Ivocerin absorption peak is set on violet spectrum (380-420nm), which slightly extends to blue spectrum range.^{10,11} This aspect might suggest to use a multiwave light-curing unit (LCU) that covers both blue and violet spectrum range. Is the use of a monowave LCU could affect the polymerization of resin-based materials? that contain alternative photoinitiators, being an important question to be answered.

The light-curing protocol is a crucial step for luting veneers. Exposure time can influence on degree of conversion (DC) of monomers.^{12,13} Increase the exposure time could led higher DC values, especially when curing through ceramics.^{14, 15} On the other hand, decreasing on the exposure time lower mechanical properties are generated.¹⁶ The photoactivation technique is also an important point to know. Intermittent photoactivation presented lower values of Knoop hardness and DC, causing a decrease on mechanical properties of resin-based materials.¹⁷ Clinicians have been

using a sweeping movement during resin cement used for luting ceramic veneers aiming to reduce the final time.

Therefore, the aim of this study was to evaluate the effect of sweeping monowaves and polywave LCU using reduced time and total time on the degree of conversion of light-cured resin cements with different photoinitiators used for luting laminate veneers. The null hypotheses tested were: 1) DC would not be affected by photoactivation technique and exposure time; 2) DC would not be affected by LCU type.

MATERIAL AND METHODS

Study Design

Two light-cured resin cements with different photoinitiators were used: Variolink Esthetic LC (Ivoclar Vivadent, Schaan, Liechtenstein); and Allcem Veneer APS (FGM, Joinville, SC, Brazil). The luting materials information is summarized in Table 1. Three commercial light-curing-units (LCUs) were used in this study: Bluephase G2 (Ivoclar Vivadent, Schaan, Liechtenstein; Elipar Deep Cure-L (3M Oral Care, St. Paul, MN, USA); and Emitter C (Schuster, Santa Maria, RS, Brazil). The information of LCUs was summarized on Table 2. Three photoactivation techniques were tested: Localized technique for 10 and 40s; Sweeping technique for 10 and 40s; Sweeping technique for 60 and 240s. A device to simulate the sweeping movement on six anterior teeth was created and used on this study. The LCUs were characterized on Marc Resin Calibrator and Degree of Conversion were performed 24 hours after light-curing resin cements.

Teeth matrix creation

Six bovine incisors with similar shade were selected, submitted to prophylaxis and had their roots removed with a high-speed water-cooled diamond disc (American Burrs, Palhoça, SC, Brazil). The teeth were reshaped using a high-speed diamond bur (No. 4138, KG Sorensen, Cotia, São Paulo, Brazil) to get the average size of human six maxillary anterior teeth.^{18,19} To simulate the light reflection of teeth closer to clinical conditions, the teeth were included in a translucent epoxy resin (Buehler, Lake Bluff, IL, USA) maintaining the size and proportion of six maxillary anterior teeth^{18,19} and the

buccal surface were finished with 600, 800, 1000, 1200-grit sandpaper (3M-ESPE, St. Paul, MN, USA) to obtain a smooth surface followed by polishing with 6 μ m, 3 μ m, 1 μ m, 1/4 μ m-grit silicon carbide paper (Arotec, Cotia, SP, Brazil) with respective diamond polishing pastes (Arotec, Cotia, SP, Brazil) for 2 minutes long each paper using the same rpm (Fig. 1A).

Photoactivation device development and samples fabrication

A device was developed to simulate the sweeping movement (Odeme Dental Research, Luzerna, SC, Brazil) (Fig. 2). This equipment has an adjustable speed stepper motor coupled to a metal base that allows movement from the left to right canines. The tooth matrix was fixed and a device to keep the LCU on the same position was used (Odeme Dental Research, Luzerna, SC, Brazil) (Fig. 3). The speed of movement was adjusted by 5 seconds from side to side of matrix or from canine to canine tooth.

For this study, two light-cured resin cements with different photoinitiators were used (Variolink Esthetic LC, shade neutral, Ivoclar Vivadent, Schaan, Liechtenstein; and Allcem Veneer APS, shade translucent, FGM, Joinville, SC, Brazil). The luting materials information is summarized in Table 1. The luting materials were applied into 0.3-mm thick acetate sheets matrix with six holes with 4-mm diameter (n=5) (Fig.1B). The resin cement matrix was placed above the teeth matrix with holes located on the center of each tooth corresponding to the six anterior teeth. Polyester strips were placed below and above the resin cement matrix. IPS e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein) HT/A1/C14 ceramic blocks were cut in four 0.5-mm thick discs using a precision saw (Isomet 1000, Buehler, Lake Bluff, IL, USA) and crystallized in dental furnace (Programat EP 3010, Ivoclar Vivadent, Schaan, Liechtenstein). The ceramic discs were placed above the resin cement matrix (Fig. 1C). The LCU tip was maintained 1-mm above ceramic disc for light curing (Fig. 3 and Fig. 4). As the luting materials with different photoinitiators are recommended to light-curing with different LCU (Ivocerin, violet-blue spectrum; Camphorquinone, blue spectrum), three LCUs were tested on this study (Bluephase G2, Ivoclar Vivadent, Schaan, Liechtenstein; Elipar DeepCure, 3M Oral Care, St. Paul, MN, USA; and Emitter C, Schuster, Santa Maria, RS, Brazil). The information of LCUs was summarized on Table 2.

Three photoactivation techniques were tested. A localized technique corresponding to a stabilized photoactivation on each tooth for 10 and 40s. A sweeping technique from left to right and right to left on a time recommended by manufacturer to photoactivate one tooth (10 or 40s); or using sweeping technique with the total time of 6 anterior teeth (60 or 240s). The exposure time recommended for the tested resin cements were different (Table 1) so the two light-curing time was evaluated for both materials and also with three photoactivation techniques proposed.

Degree of Conversion (DC)

The degree of conversion (DC) at the top of each specimen of resin cement matrix (n=5) were assessed after 24 hours of light-curing the resin cements. The DC was determined using attenuated total reflectance/Fourier transform infrared spectroscopy (ATR/FTIR, Vertex 70, Bruker, Ettlingen, Baden-Württemberg, Germany). A preliminary readout of each uncured resin cement was recorded in absorbance spectrum by scanning the specimens 32 times over a range from 4000 to 400 cm^{-1} with a resolution of 4 cm^{-1} . A spectrum was acquired immediately after light-curing the resin cements and after dry storage at 37°C for 24 hours. The spectra were obtained between internal standard aromatic C=C bonds (1608 cm^{-1}) and aliphatic C=C bond (1638 cm^{-1}). All analyses were performed under controlled temperature (25°C±1°C) and humidity (60±5%) conditions, shielded from ambient and room light. DC was calculated from the equivalent aliphatic (1638 cm^{-1}) and aromatic (1608 cm^{-1}) ratios of cured (C) and uncured (U) resin composite specimens. The formula used to calculate the degree of conversion was $\text{DC (\%)} = (1 - \text{C/U}) \times 100$.^{20,21,22}

Characterization of Light-Curing-Units

The LCUs were evaluated on MARC Resin Calibrator (BlueLight Analytics, Halifax, NS, Canada) to characterize irradiance (mW/cm^2), spectrum emission ($\text{mW/cm}^2/\text{nm}$), peak of spectrum (nm) and radiant exposure (J/cm^2) delivered by each LCU in standard mode.

Statistical Analysis

Degree of conversion data were analyzed for normal distribution and homoscedasticity using the Shapiro-Wilk test and Levene's test, respectively. Two-way ANOVA was used to compare the main factors: photoactivation technique (3), LCU (3). Multiple comparisons were made using The Tukey Test. To analyze the effect of the

photoactivation technique on the tooth position One-way ANOVA was used for all groups isolated. All tests employed $\alpha=0.05$ significance level and all analyses were performed using Sigma Plot 12.5 (Systat Software Inc, San Jose, CA, USA).

RESULTS

Characterization of Light-Curing-Units

The results of the characterization of LCUs using Marc Resin Calibrator are shown on Figure 5 and Table 3. The irradiance and radiant exposure decreased about half for all the LCUs tested when 0.5-mm ceramic is interposed between sensor and LCU. In addition, when making the samples a polyester strip was used above the matrix that adds up a drop of 1.25 J/cm² on total energy and 64 mW/cm² on maximum irradiance presented on Table 3.

Degree of Conversion (DC, %)

Figure 6 indicate the mean and standard deviation of degree of conversion (%) of both luting materials with three LCUs. Two-way ANOVA showed significant differences between photoactivation techniques ($P < 0.001$). The localized activation for 40s resulted in significantly higher DC for both resin cements than sweeping technique using reduced or total time for both exposure time used. In general, the exposure time of 40 seconds resulted in higher DC for both resin cements tested. Significant difference was found for DC values of tested LCUs when localized photoactivation with 40 seconds using Emitter C than when used Bluephase G2 and Elipar Deep Cure-L. No difference was detected between LCUs using localized photoactivation technique with exposure time of 10 seconds. When Emitter C was used for both reduced or total time sweeping technique the lowest DC values was obtained.

The DC of both luting materials with three LCUs tested analyzing the difference by tooth location of six teeth (canine to canine) with exposure time of 40 seconds was presented on Figure 7. One-way ANOVA showed no statistical difference between DC

values of different tooth location when 40 seconds was used for all groups. However, when 10s of exposure time significant difference was found with sweeping technique with samples at the canine location presented higher DC values than other teeth locations Figure 8.

DISCUSSION

This study evaluated the influence of photoactivation techniques with different monowaves and polywave LCUs on the DC values of resin cements. According to the tested conditions, the null hypotheses evaluated in this study were rejected. The results showed that photoactivation technique, exposure time and LCU type showed statistically significant differences on DC values. DC of resin cements with different photoinitiators have not relation with tested LCUs.

According to the characterization of the LCUs on Marc Resin Calibrator it is possible to evaluate the differences between the mean of irradiance and the total energy delivered by them. However, when 0.5-mm ceramic was interposed between LCU tip and sensor the irradiance and radiant exposure values approach by attenuation of light caused by ceramic disc. Emitter C presented lower irradiance and radiant exposure values, especially when the reduced sweeping technique was used.

The analyses of the degree of conversion was done 24 hours after the photopolymerization of the samples in the FTIR device. The results reveal that the DC was higher in the localized technique with 40 seconds of exposure time. This result shows that using the recommended time by the manufacturer, for each tooth, using localized technique, is the most appropriate to reach the greater polymerization of the material. However, when using the sweeping technique, the movement from one side to another causes a lower DC, once that the LCU spend much time passing over the holes containing luting material, not light-curing correctly the samples, which is aggravated by the 0.5-mm ceramic discs, that simulate the laminate veneers. Besides that, the sweeping movement causes slightly greater exposure on the extremities due to the movement that the device makes to change the direction of movement from one side to another. This may explain the higher DC values on canine location than the other teeth when reduced sweeping technique was used because once the exposure time is slightly increased it tends to increase the DC.¹² Nevertheless, the difference on

DC by location of teeth that was shown with 10 seconds sweeping technique was compensated when increased the time of exposure to 60 seconds.

An interesting question about this study was that increasing the exposure time of sweeping technique (240s) did not reach the same DC values of those obtained with localized technique (40s). Even being the 240s sweeping technique corresponding to 40s to each tooth (six anterior teeth). This may be justified by an interruption on the polymerization reaction of resin cement that may result on lower DC values, although more studies need to be done to evaluate this fact. This situation may be similar to the intermittent light photoactivation technique which led to lower KHN and DC values.¹⁷

Regarding the resin cements with different photoinitiators and the use of monowaves and polywave LCU the results of this study demonstrated no significant influence on DC values. Figure 5A shown different wavelength peaks of LCUs and it is possible to analyze that the peak of Bluephase G2 on violet spectrum range has lower irradiance than the blue spectrum peak being about four times lower or corresponding to only 25% of total irradiance and radiant exposure delivered by LCU, the same was found on another study.¹⁰ Besides that, Ivocerin absorption is set on violet spectrum and also extends to blue spectrum range,^{10,11} so the use of a monowave LCUs seems to be equally effective to light-cure resin cement with Ivocerin photoinitiator as multiwave LCU is, since no statistical difference was found between the use of the three LCUs with both resin cement tested.

In this study the resin cement sample had 4.0mm in diameter, further studies should to be performed to analyze larger diameter of sample size of central incisor buccal area and the position of violet LED of multiwave LCU.

CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions can be drawn:

1. The localized photoactivation for 40s resulted in higher and more homogeneous DC values;
2. The reduced sweeping technique resulted in lower DC values, the sweeping time did not reach the DC values obtained as localized technique;

3. When using sweeping technique, the Emitter C presented lower DC than Elipar Deep Cure and Bluephase G2.

4. DC of resin cements with different photoinitiators was not affected by light curing with monowaves or polywave LCU type.

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TABLES

Table 1. Luting materials used in this study.

Luting Materials	Shade	Light activation time (s)	Composition	Filler (wt%)	Photoinitiator	Manufacturer
Allcem Veneer APS	Trans	40	Methacrylic monomers, Barium aluminosilicate glasses, silicon dioxide	63.0	Camphorquinone, APS	FGM, Joinville, SC, Brazil
Variolink Esthetic LC	Neutral	10	Bis-GMA, UDMA, TEGDMA, ytterbium trifluoride, boroaluminofluorosilicate glass, spheroidal mixed oxide, benzoylperoxide, stabilizers, pigments	60-68	Ivocerin	Ivoclar Vivadent, Schaan, Liechtenstein

Table 2. The specifications of light-curing units (LCUs) used in this study.

Light Curing Units/LCU	LCU serial number	LCU type/ Wavelength emission	Battery/ Mains	Tip/Light conductor	Manufacturer
Bluephase G2	236679	LED/multi-peak	Mains	Optical fiber/black	Ivoclar Vivadent, Schaan, Liechtenstein
Elipar DeepCure-L	932125030659	LED/monowave	Battery	Optical fiber/black	3M-ESPE, St Paul, MN, USA
Emitter C	L1351617C	LED/monowave	Battery	Optical fiber/translucent	Schuster, Santa Maria, RS, Brazil

Table 3. The characterization of light-curing units (LCUs) on Marc Resin Calibrator with and without ceramic interposition.

Light Curing Units/LCU	Presence of 0.5-mm e.max CAD	Mean of Irradiance (mW/cm ²)	Total energy / Radiant Exposure – 20s (J/cm ²)	Peak of emission spectrum (nm)
Bluephase G2	-	1179.00	23.79	457
	w/ 0.5-mm	641.00	12.92	
Elipar DeepCure-L	-	1887.00	37.64	451
	w/ 0.5-mm	864.00	17.44	
Emitter C	-	1211.00	24.00	453
	w/ 0.5-mm	601.00	12.04	

FIGURES



Figure 1. Teeth matrix used on this study. A) Teeth matrix simulating six anterior teeth; B) 0.3-mm thick resin cement matrix with six holes to make luting materials samples; C) 0.5-mm ceramic discs placed above the resin cement matrix.

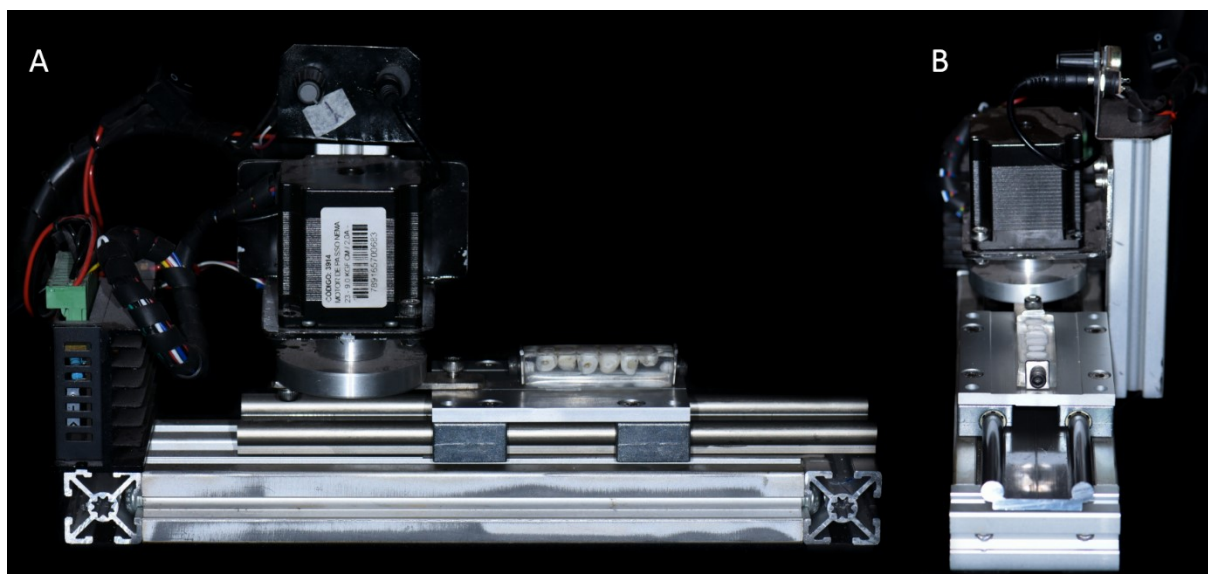


Figure 2. Device used to simulate the sweeping technique. A) Frontal view; B) Lateral view.

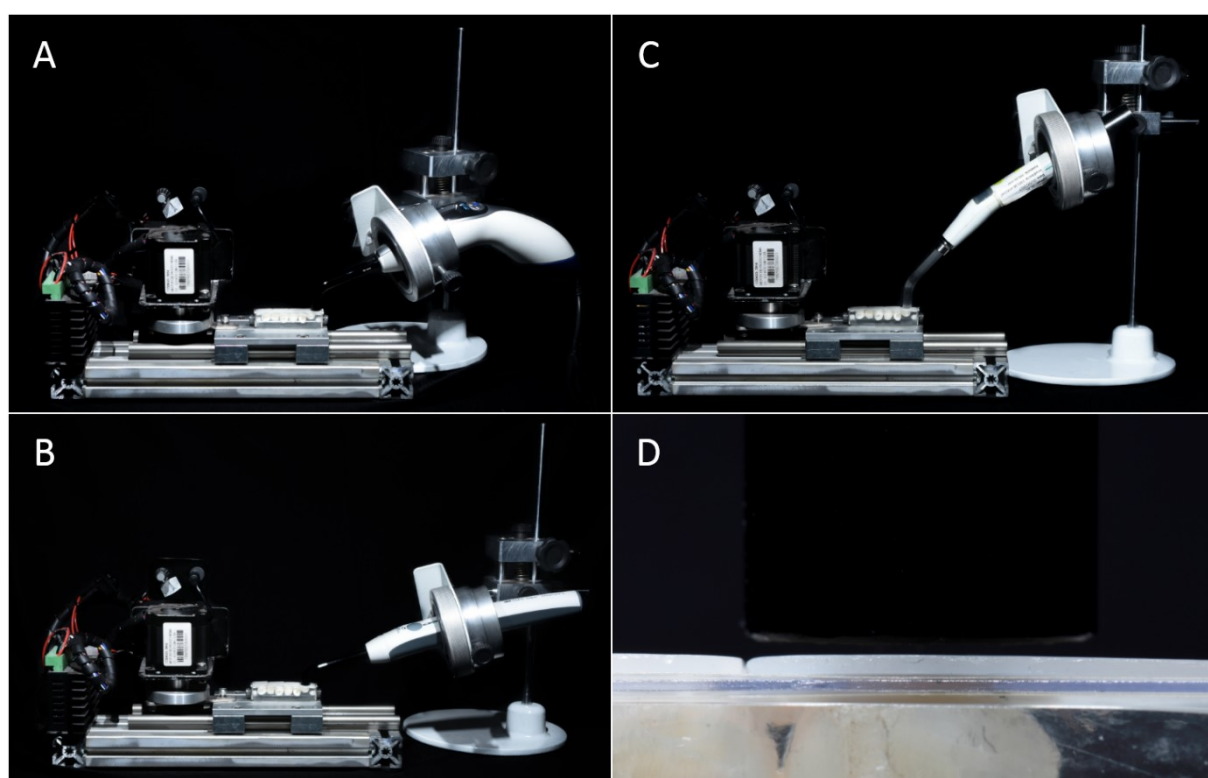


Figure 3. Device to keep the LCU on the same position during the tests. A) Setup with Bluephase G2; B) Setup with Elipar DeepCure-L; C) Setup with Emitter C; D) LCU tip positioned 1-mm above the ceramic disc.

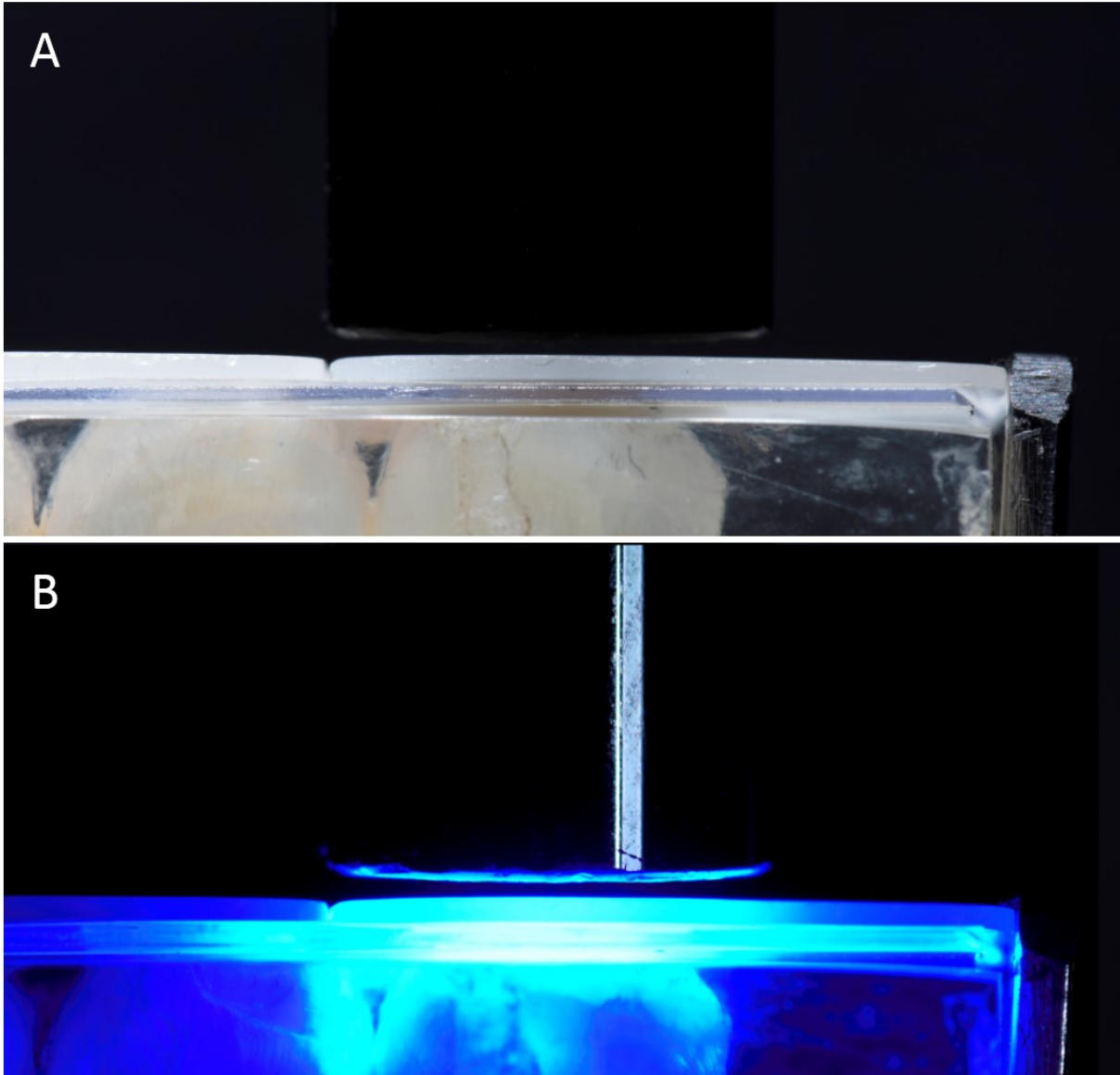


Figure 4. Position of LCU tip during the tests. A) LCU tip positioned 1-mm above ceramic disc; B) LCU during light activation.

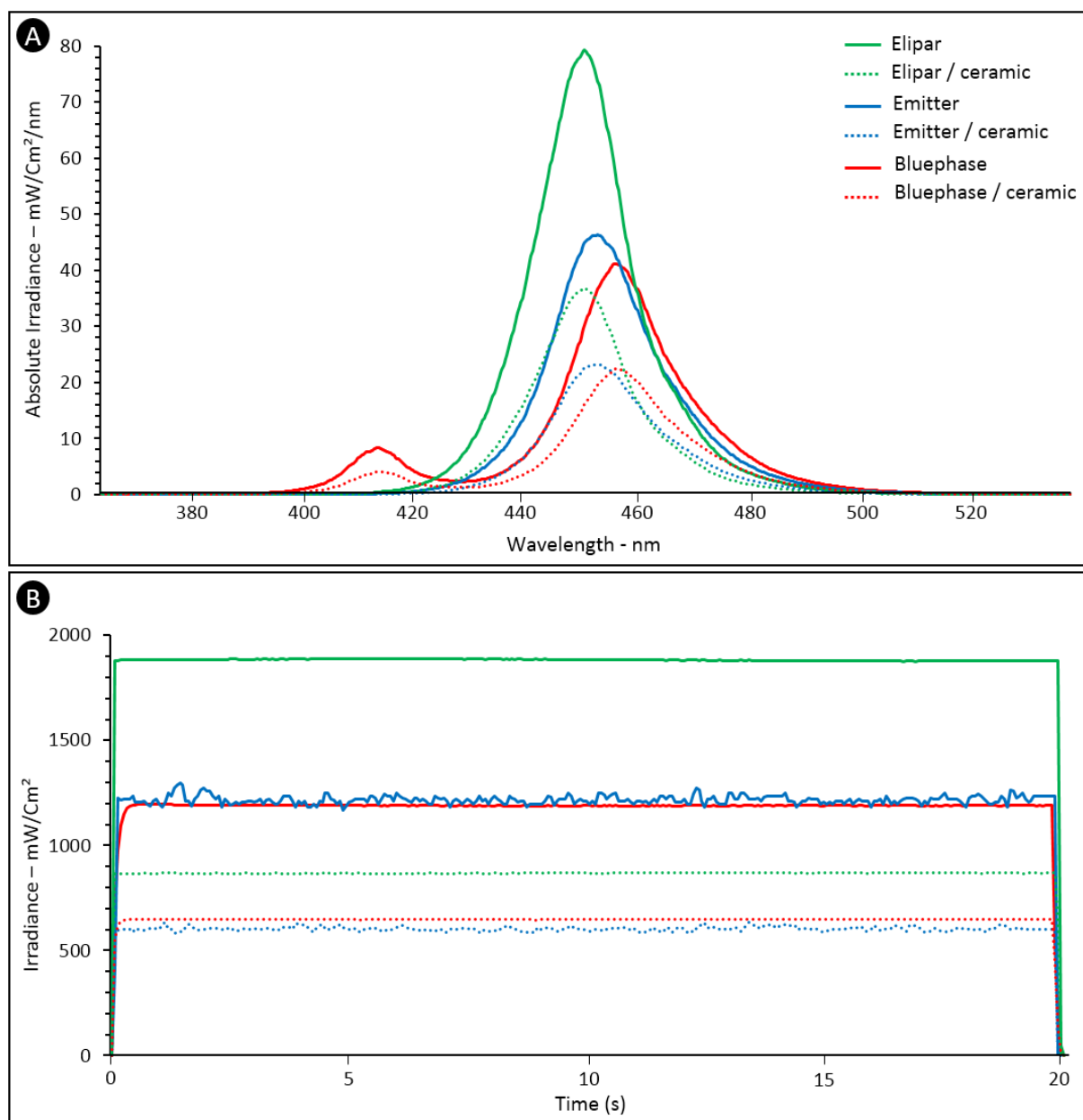


Figure 5. Characterization of LCUs on Marc Resin Calibrator. A) Emission spectrum showing the different wavelength peaks of LCUs; B) Irradiance of the LCUs.

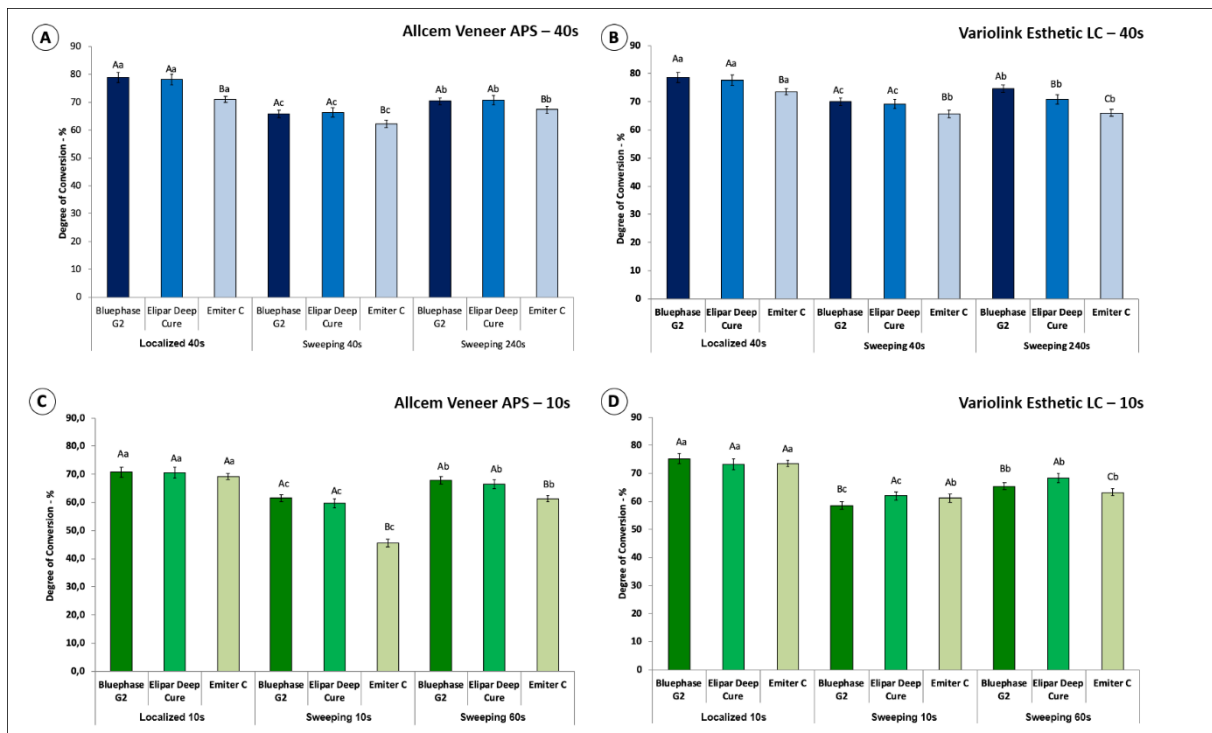


Figure 6. Degree of conversion of both luting materials with the three LCUs. Different uppercase letters indicate statistical difference between LCUs inside the same technique. Different lowercase letters indicate statistical difference between the same LCU with three photoactivation techniques. A) Exposure time of 40s with Allcem Veneer; B) Exposure time of 40s with Variolink Esthetic; C) Exposure time of 10s with Allcem Veneer; D) Exposure time of 10s with Variolink Esthetic.

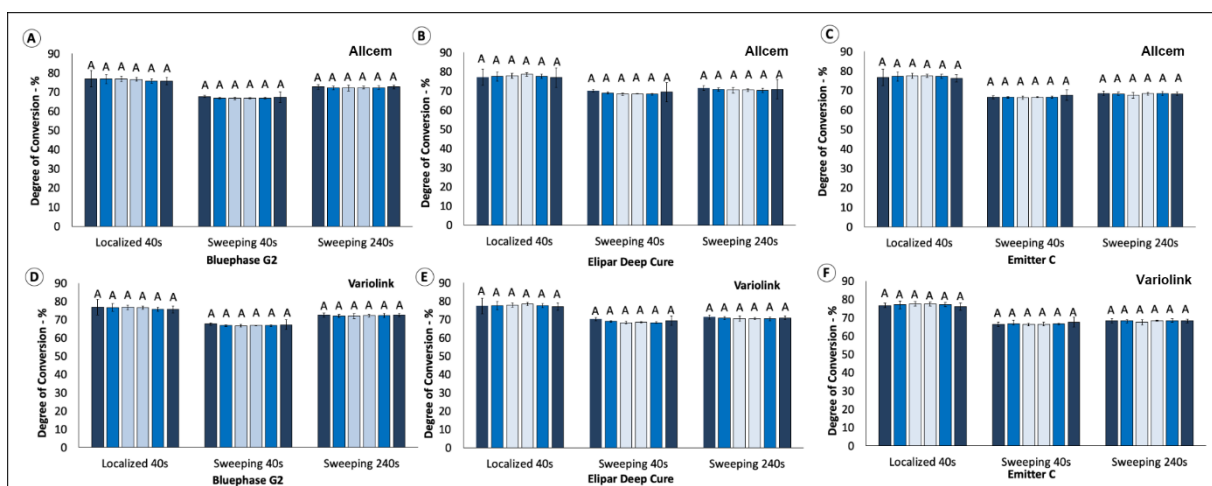


Figure 7. Degree of conversion of both luting materials with three LCUs analyzing the difference by tooth location (canine to canine) with exposure time of 40 seconds. A)

Allcem/Bluephase; B) Allcem/Elipar; C) Allcem/Emitter; D) Variolink/Bluephase; E) Variolink/Elipar; F) Variolink/Emitter.

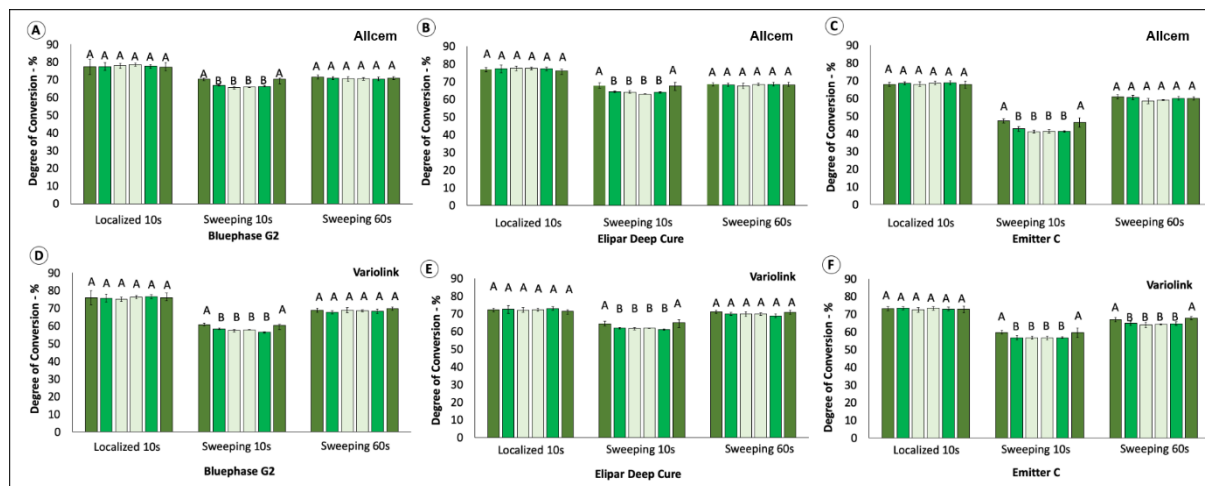


Figure 8. Degree of conversion of both luting materials with three LCUs analyzing the difference by tooth location (canine to canine) with exposure time of 10 seconds. A) Allcem/Bluephase; B) Allcem/Elipar; C) Allcem/Emitter; D) Variolink/Bluephase; E) Variolink/Elipar; F) Variolink/Emitter.