Rodrigo José Moreira

Effect of light source and mouth opening on photoactivation of bulk fill resins in molars

Efeito da fonte de luz e da abertura de boca na fotoativação de resinas bulk fill em molares

Dissertação apresentada à Faculdade de Odontologia da Universidade Federal de Uberlândia, para obtenção do Título de Mestre em Odontologia – Área de Concentração em Clínica Odontológica Integrada.

Uberlândia, 2019

Rodrigo José Moreira

Efeito da fonte de luz e da abertura de boca na fotoativação de resinas compostas bulk fill em molares

Effect of light curing unit and mouth opening on light activation of bulk fill composite resins in molars

Dissertação apresentada ao Programa de Pós-Graduação em Odontologia da Faculdade de Odontologia da Universidade Federal de Uberlândia, como requisito parcial para obtenção do Título de Mestre em Odontologia – Área de Concentração em Clínica Odontológica Integrada.

Orientador: Prof. Carlos José Soares

Banca Examinadora:

Prof. Carlos José Soares, UFU

Prof. Paulo Sérgio Quagliatto, UFU

Prof. Valéria Bisinotto Goti, UNITRI

Suplentes

Prof. Murilo de Sousa Menezes

Prof. João Henrique de Lima

Uberlândia, 2019

UNIVERSIDADE FEDERAL DE UBERLÂNDIA
Coordenação do Programa de Pós-Graduação em Odontologia
Av. Pará, 1720, Bloco 4L, Anexo B, Sala 35 - Bairro Umuarama, Uberlândia-MG, CEP 38400-902
Telefone: (34) 3225-8115/8108 - www.ppgoufu.com - copod@umuarama.ufu.br

ATA DE DEFESA - PÓS-GRADUAÇÃO

Programa de Pós-Graduação em:	Odontologia				
Defesa de:	Dissertação de Mestrado Acadêmico - PPPGO				
Data:	Vinte e Oito de Agosto de Dois Mil e Dezenove	Hora de início:	14:30	Hora de encerramento:	16:30
Matrícula do Discente:	11712ODO020				
Nome do Discente:	Rodrigo José Moreira				
Título do Trabalho:	Efeito da fonte de luz e abertura de boca na fotoativação de resinas compostas bulk fill em molares				
Área de concentração:	Clínica Odontológica Integrada				
Linha de pesquisa:	Biomecânica Aplicada à Odontologia				
Projeto de Pesquisa de vinculação:	Biomecânica Aplicada à Odontologia				

Reuniu-se no Anfiteatro/Sala 23 - Bloco 4L - Anexo A, Campus Umuarama, da Universidade Federal de Uberlândia, a Banca Examinadora, designada pelo Colegiado do Programa de Pós-graduação em Odontologia, assim composta: Professores Doutores: Paulo Sérgio Quagliatto (UFU); Valéria Bisinoto Gotti (UNITRI) e Carlos José Soares (UFU) orientador(a) do(a) candidato(a).

Iniciando os trabalhos o(a) presidente da mesa, Dr(a). Carlos José Soares, apresentou a Comissão Examinadora e o candidato(a), agradeceu a presença do público, e concedeu ao Discente a palavra para a exposição do seu trabalho. A duração da apresentação do Discente e o tempo de arguição e resposta foram conforme as normas do Programa.

A seguir o senhor(a) presidente concedeu a palavra, pela ordem sucessivamente, aos(às) examinadores(as), que passaram a arguir o(a) candidato(a). Ultimada a arguição, que se desenvolveu dentro dos termos regimentais, a Banca, em sessão secreta, atribuiu o resultado final, considerando o(a) candidato(a):

Aprovado(a).

Esta defesa faz parte dos requisitos necessários à obtenção do título de Mestre.

O competente diploma será expedido após cumprimento dos demais requisitos, conforme as normas do Programa, a legislação pertinente e a regulamentação interna da UFU.

Nada mais havendo a tratar foram encerrados os trabalhos. Foi lavrada a presente ata que após lida e achada conforme foi assinada pela Banca Examinadora.

Dados Internacionais de Catalogação na Publicação (CIP)
Sistema de Bibliotecas da UFU, MG, Brasil.

M838e 2019

Moreira, Rodrigo José, 1977
Efeito da fonte de luz e da abertura de boca na fotoativação de resinas compostas bulk fill em molares = Effect of light curing unit and mouth opening on light activation of bulk fill composite resins in molars [recurso eletrônico] / Rodrigo José Moreira. - 2019.

Orientador: Carlos José Soares.
Dissertação (mestrado) - Universidade Federal de Uberlândia, Programa de Pós-Graduação em Odontologia.
Modo de acesso: Internet.
Disponível em: http://dx.doi.org/10.14393/ufu.di.2019.1359
Inclui bibliografia.
Inclui ilustrações.

1. Odontologia. 2. Resinas dentárias. 3. Molares. 4. Polimerização. I. Soares, Carlos José, 1965, (Orient.) II. Universidade Federal de Uberlândia. Programa de Pós-Graduação em Odontologia. III. Título.

CDU: 616.314

Angela Aparecida Vicentini Tzi Tziboy – CRB-6/947

RESUMO

Este estudo teve por objetivo avaliar a influência do tipo de fonte de luz e da dimensão de abertura de boca na fotoativação de resinas bulk fill de alta viscosidade em cavidades classe II em segundo molar inferior. Oitenta molares humanos receberam preparos cavitários MOD com 3/5 da distância intercuspídea e profundidade de 4mm na caixa oclusal e 5 mm nas caixas proximais e foram divididos em 8 grupos formados pelos 3 fatores em estudo (fonte de luz – 2 níveis; abertura de boca – 2 níveis e resina bulk fill – 2 níveis). Os dentes foram restaurados com resina composta bulk fill de alta viscosidade (Opus Bulk Fill APS, FGM ou Filtek Bulk Fill One, 3M-ESPE) empregando duas fontes de luz com diferentes designs: corpo retilíneo (VALO Cordless, Ultradent) e corpo angulado (radii-Cal, SDI). Para simular a abertura interincisal foi desenvolvido dispositivo sistema de controle abertura de boca em manequim odontológico, permitindo duas condições de abertura de boca: limitada (25 mm) e normal (45 mm). Os dentes foram submetidos a fadiga térmica por 10.000 ciclos entre 5 - 55º C e fadiga mecânica por carregamento oclusal de 50N por 1.200.000 ciclos com frequência de 2 Hz. Os dentes foram seccionados no sentido mesio-distal, e após polimento foi medido o grau de conversão (DC, %) nas caixas proximais mesial e distal e na caixa oclusal, à mesma profundidade (n=5). Foi avaliada a dissolução de monômeros não polimerizados sendo obtidas imagens padronizadas antes e após a imersão por 24 horas em tetrahidrofurano. Foi avaliado a infiltração marginal com nitrato de prata por meio de microscopia eletrônica de varredura. Os dados DC foram analisados por meio de análise de variância em 3 fatores seguido de teste de Tukey(α=0.05). Resultados: Os valores de %DC das restaurações fotoativadas com VALO Cordless não foram influenciados não foram influenciadas pelo tipo de resina nem pela abertura de boca enquanto que os valores para as restaurações fotoativadas com a fonte radii-cal foram influenciadas pelo tipo de resina , abertura de boca e região da restauração.A fonte de luz radii-cal gerou maior dificuldade de posicionamento na menor abertura de boca, apresentando redução na emissão de irradiância e do espectro de luz com a profundidade da cavidade. A dissolução de monômeros foi mínima na maioria das amostras testadas, embora as amostras construídas com fonte de luz radii-cal e abertura de boca de 25 mm apresentaram ligeiro aumento da dissolução.Conclusões: Fontes luminosas com corpo angulado fornecem menor irradiância as cavidades proximais de dentes posteriores, resultando em pior desempenho na ativação das resinas bulk fill nas caixas proximais. Na abertura de boca de 45mm as fontes de luz não influenciaram no desempenho das resinas compostas.

Palavras Chaves: Resinas bulk fill, dentes posteriores, abertura de boca, fontes de lz, polimerização.

ABSTRACT

The aim of this study was to evaluate the influence of light source type and mouth opening dimension on the photoactivation of high viscosity bulk fill resins in lower second molar class II cavities. Eighty human molars received MOD cavity preparations with 3/5 of the intercuspal distance and 4mm depth in the occlusal box and 5mm in the proximal boxes and were divided into 8 groups formed by the 3 factors under study (light source - 2 levels; mouth opening - 2 levels and bulk fill resin - 2 levels). The teeth were restored with high viscosity bulk fill composite resin (Opus Bulk Fill APS, FGM or Filtek Bulk Fill One, 3M-ESPE) employing two light sources with different designs: straight body (VALO Cordless, Ultradent) and angled body (radii-Cal, SDI). To simulate the interincisal opening, a mouth opening control system was developed, allowing two mouth opening conditions: limited (25 mm) and normal (45 mm). The teeth were subjected to thermal fatigue for 10,000 cycles at 5 - 55o C and mechanical fatigue by 50N occlusal loading for 1,200,000 cycles at a frequency of 2 Hz. The teeth were sectioned in the mesio-distal direction, and after polishing the teeth, the degree of conversion (DC,%) were measured in the mesial and distal proximal boxes and in the occlusal box at the same depth (n = 5). Dissolution of unpolymerized monomers was evaluated and standardized images were obtained before and after immersion for 24 hours in tetrahydrofuran. Marginal infiltration with silver nitrate was evaluated by scanning electron microscopy. DC data were analyzed by 3-way analysis of variance followed by Tukey's test ($\alpha = 0.05$).Results: Values of% DC of VALO Cordless photoactivated restorations were not influenced by resin type or mouth opening, while values for radii-cal photoactivated restorations were influenced by resin type, aperture. The radii-cal light source caused greater difficulty in positioning at the smallest mouth opening, showing a reduction in irradiance emission and light spectrum with the depth of the cavity. Monomer dissolution was minimal in most of the samples tested, although samples constructed with radii-cal light source and 25 mm mouth opening showed slightly increased dissolution. Conclusions: Light sources with angled body provide less irradiance to the proximal cavities of posterior teeth, resulting in worse performance in the activation of bulk fill resins in the proximal boxes. In the 45mm mouth opening the light sources did not influence the performance of composite resins.

Keywords: Bulk fill resins, posterior teeth, mouth opening, light sources, polymerization.

INTRODUÇÃO E REFERENCIAL TEÓRICO

Desde o surgimento das resinas compostas, a qualidade da polimerização vem sendo motivo de vários estudos objetivando melhorar o desempenho destes materiais. Novas tecnologias vêm surgindo para fornecer a quantidade de luz necessária para uma eficiente conversão dos monômeros constituintes básicos destes materiais(Rode *et al.*, 2007). Por muitos anos, o uso de incrementos com até 2mm de espessura tem sido preconizado para favorecer uma maior polimerização e controlar as tensões de contração de polimerização (Omran *et al.*, 2017; Braga *et al.*, 2018). Entretanto, essa técnica em cavidades mais profundas consome mais tempo e pode favorecer o aparecimento de bolhas e ainda pode comprometer a conversão dos monômeros em áreas mais profundas devido à distância da fonte ativadora(Rode *et al.*, 2007; F *et al.*, 2016). A contínua evolução dos materiais restauradores diretos fez surgir mais recentemente mais um grupo de materiais que são as resinas compostas bulk-fill que tem chamado a atenção devido à possibilidade de se utilizar camadas entre 4 a 5 mm de espessura, dependendo da marca (Par *et al.*, 2015; Gamarra *et al.*, 2018). Assim, tanto cirurgiões dentistas quanto fabricantes de fontes de foto ativação precisam estar atentos se a luz consegue ativar resinas compostas usando tempo de exposição e incrementos tecnicamente relevantes(Alshaafi *et al.*, 2016).

A estruturação de cadeias organizadas de monômeros em polímeros determina o grau de conversão que está relacionado com a energia emitida e recebida pelo material (Kim *et al.*, 2015; Shimokawa *et al.*, 2017). O grau de conversão das resinas compostas reflete diretamente às suas propriedades mecânicas. Dentre elas, a dureza correlaciona fortemente com o grau de conversão (Santos *et al.*, 2007). Uma adequada fotoativação tem papel importante na longevidade das restaurações diretas. Esse procedimento requer intensidade luminosa suficiente e adequado comprimento de onda para ativar o fotoiniciador presente nas resinas compostas(Carvalho *et al.*, 2012). Alguns fatores como a fonte de fotoativação e a dimensão de abertura de boca podem limitar o grau de conversão de resinas compostas. O acesso da fonte de luz pode ser limitado pela menor abertura de boca em crianças por apresentam uma menor abertura de boca (Mezitis *et al.*, 1989; Fatima *et al.*, 2016), ou ainda ser reflexo de causa patológica como deslocamento de disco da articulação temporo-mandibular (Jiang *et al.*, 2016) e osteoartrose da ATM (Levorova *et al.*, 2016), ou até pela não cooperação do paciente. Esse problema afeta principalmente dentes posteriores (Harun *et al.*, 2014). Vários trabalhos definiram a amplitude média de abertura de boca variando entre 45 mm em adultos e 25 mm em pacientes com limitação patológica ou pediátricos(Lewis *et al.*, 2001; Zawawi *et al.*, 2003; Abou-Atme *et al.*, 2008; Saund *et al.*, 2012; De Moraes Baldrighi *et al.*, 2016).

Algumas marcas de fontes de luz encontradas no mercado brasileiro têm dificuldade de fornecer energia suficiente para ativação da canforoquinona (Soares et al., 2017), isso pode estar ligado a posição e profundidade da cavidade, ou à potência ou pelo design que interfere no adequado posicionamento no interior da cavidade bucal. Se há efeito limitador na ativação da resina composta pela luz, o mesmo poderá acontecer com o sistema adesivo aplicado previamente. A qualidade do selamento marginal depende da adequada integração entre sistema adesivo, substrato e resina composta (Kermanshah e Khorsandian, 2017; Mosharrafian *et al.*, 2017) e também da adequada fotoativação. Nas resinas “bulk fill”, que podem ser inseridas em incrementos de 4 a 5 mm, a polimerização ocorre devido a características desses materiais que diminuem as tensões de polimerização (Rosatto et al., 2015); e à uma maior translucidez, que permite uma penetração mais profunda da luz (Gamarra *et al.*, 2018). Porém de nada adiantaria reduzir tensões de contração de polimerização se as mesmas não apresentam adequado grau de conversão e boa adaptação e integridade com as paredes da cavidade. Dentro deste contexto, busca-se um equilíbrio entre adequada polimerização com menos tensões geradas.

1. CAPÍTULO 1

Artigo 1

Effect of light source and mouth opening on photoactivation of bulk fill resins in molars

***Artigo a ser enviado para o periódico Journal of Operative Dentistry**

INTRODUCTION

Since the emergence of composite resins, the quality of polymerization has been the subject of several studies aiming to improve the mechanical and clinical performance of these materials. New technologies are emerging to provide the amount of light needed to efficiently convert the basic constituent monomers of these materials (1). The continuous evolution of direct restorative materials has recently brought about a variation of posterior-tooth composite resins, which are bulk-fill composite resins, which allow insertion in increments of between 4 and 5 mm thickness (2, 3). With this greater thickness of material, greater attention should be paid to the amount of light that can reach the full depth of this resin mass (4).

Proper photoactivation plays an important role in the longevity of direct restorations (5, 6). This procedure requires sufficient light intensity and adequate wavelength to activate the photoinitiator present in the composite resins (7). The structuring of organized chains of monomers in polymers determines the degree of conversion that relates to the energy emitted and received by the material (8, 9). The degree of conversion of composite resins directly reflects their mechanical properties (7). Among them, the hardness of the material strongly correlates with the degree of conversion (10). Some factors such as photoactivation source and mouth opening dimension may limit the degree of conversion of resins composites by access limitation and intensity and homogeneity of light distribution emitted for restorations, especially in posterior teeth, since adequate polymerization depends on the total available energy (11). Light source access may be limited by the smaller mouth opening in children because they have a lower mouth opening capacity (12, 13). This condition may also be a reflection of pathological causes such as temporomandibular joint disc displacement (14) and TMJ osteoarthritis (15) trismus, chronic muscle pain, or even the patient's non-cooperation. The average amplitude of mouth opening ranges from 45 mm in adults to 25 mm in patients with pathological or pediatric limitation (16-20).

Some light sources found in the Brazilian market find it difficult to provide sufficient energy to activate camphorquinone (21). This may be linked to the low wattage and irradiance (22), the inhomogeneous distribution of light at the active end of the device (23, 24), and its design that ultimately limits correct positioning in posterior regions (25). On the other hand, low power, smaller active tip diameter or poor light distribution at the active tip can also compromise the performance of photoactivation in large cavities (24, 26). In bulk fill resins, deeper layer polymerization occurs due to changes in materials and their greater translucency, which allows deeper penetration of light (3). These materials also have the characteristics of generating lower levels of polymerization shrinkage stresses (27). Few studies are found in the literature that simulate the mouth opening conditions, associated with the design of different light sources and their reflection on the polymerization quality of class II cavities in posterior teeth made with bulk fill resins. Therefore, this study aimed to measure the degree of conversion, dissolution of non-reactive monomers and the integrity and marginal infiltration of class II restorations made with two bulk fill resins of different compositions in lower molars which, when activated with sources of Light with straight and angled design simulating normal and limited aperture condition could lead to different conversion results. The null hypothesis tested was that the design of the light source bound to normal or limited mouth opening would not interfere with the polymerization effectiveness and marginal integrity of class II composite filler restorations.

METHODS AND MATERIALS

Light sources characterization

Table 1 presents the characteristics of the bulk fill resins tested. The characteristics of the two light sources tested are described in Table 2. The active tips of the light sources were measured with a digital caliper (Mitutoyo CD15, Mitutoyo Co, Kawasaki, Japan).

Irradiance (mW / cm2) and emitted spectrum (mW / cm2 / nm) were calculated for both light sources using the MARC Resin Calibrator (BlueLight Analitics, Halifax, Canada). Measurements were made 5 times in the control condition with the tip touching the top sensor of the MARC, and interposing a molar with MOD preparation at the same depth as the samples to be restored. The MOD cavity was filled with polyester-based impression material (Impregum F, Dentsply Sirona), the molar crown was included in polystyrene resin, containing the metal matrices (Unimatrix, TDV Dental Ltd, Pomerode, SC, Brazil). It was then sectioned with a double-sided diamond blade on precision cutter (Isomet 1000, Bruker, Lake Bluff, IL, USA) at the height of the proximal boxes, exposing the preparation base at the same boundary depth as the proximal boxes.

Control: The active tips of the handsets were positioned directly over the MARC-RC top sensor (Figure 1).

Mesial and distal proximal box: To determine the irradiance and the light spectrum that reached the depth of the cavity without the interposition of the resin, the resulting inclination of each device was initially obtained under the 25mm and 45mm mouth opening conditions (11). The light sources were stabilized in a fixture device (ODEME, Lucerna, SC, Brazil). The prepared tooth sample was positioned over the sensor in the region of the proximal boxes and the light sources were activated (n = 5).

Calculation of active tip area and power (mW)

Active tip diameters of VALO Cordless and radii cal light sources were measured with a digital caliper (Mitutoyo CD15, Mitutoyo Co, Kawasaki, Japan). The active tip area was calculated by the circle area formula ($A = \pi r ^ 2$). The irradiated power (mW) was measured using a 10 watt sensor laser laboratory potentiometer (FieldMate laser power meter, Coherent Inc., Santa Clara, CA, USA). The devices were loaded at full power and the power was then measured with their tip near the sensor. The light fixture has been fixed by means of a fixation system that provides stability of the light source.

Cavity Preparation and Restoration Making

After CEP approval (96032718.7.0000.5152), 80 lower third molars were selected, with similar dimensions and shape, not varying by more than 10% of the average coronary volume measurements. The teeth were included in polystyrene resin (Cristal, Piracicaba, SP, Brazil) according to the principles described by Soares et al. in 2005 (28) and randomly divided into 8 groups (n = 10). Mesio-occlusal-distal cavities were made 4 mm deep in the occlusal portion and 5 mm deep in the proximal cases from the tip of the highest cusp and with a buccolingual dimension corresponding to 3/5 of the distance between the cusps. The preparations were performed in a standardized preparation machine (29), professional single operator, using high speed N 3099 (KG Sorensen, Barueri, SP, Brazil) diamond tip (Kavo do Brasil, Joinville, SC, Brazil) under constant irrigation, being changed every 5 preparations. The teeth included were coupled to a mouth opening simulator device in the position of the lower second molar (30). This device simulates the limiting situation of the introduction of the light source into the patients oral cavity. With a digital caliper, mouth openings of 25 mm were measured for patients with limited opening and 45 mm for patients with wide mouth opening.

The eight experimental groups were generated by the interaction between 3 factors under study:

1. Light sources (2 levels): Rectilinear body (Valo Cordless, Ultradent, South Jordan, UT, USA) and angled body (radii-cal, SDI, Victoria, Australia);
2. Mouth opening dimension (2 levels): normal (45mm) and limited (25mm);
3. Type of bulk fill composite resin (2 levels): Filtek Bulk Fill One (3M ESPE, St. Paul, MN, USA) and Opus Bulk Fill APS (FGM, Joinville, SC, Brazil).

The samples, immediately after the installation of the steel dies (Unimatrix, TDV Dental Ltda, Pomerode, Santa Catarina, Brazil) were conditioned on 37% phosphoric acid enamel (Condac, FGM) for 30s and then washed. The universal adhesive (Ambar Universal, FGM for Opus Bulk Fill APS Resin; and Universal Single Bond for Filtek Bulk Fill One) was actively applied for 20s to dentin and enamel, dried and then applied a new layer and photoactivated for 10s. Bulk fill resin increments were condensed in the proximal and then occlusal boxes and then photoactivated for 20 seconds in both the mesial and distal portions of the crown. All restorative protocols followed the manufacturers recommendations.

Thermomechanical Fatigue

Marginal excesses were removed using diamond tips (KG Sorensen, Cotia, SP, Brazil) and finishing sandpaper (3M ESPE, St Paul, MN, USA) and Enhance polishing silicon tips (Dentsply, York, PA, USA). From each group were randomly selected 5 samples that were first submitted to thermomechanical fatigue process. Thermal fatigue was performed in a thermal cycling machine (Odeme, Lucerna, SC, Brazil), performing 10,000 cycles between 5, 37 and 55□C baths for 30s in each bath, simulating 5-year aging (31). Then, the samples were subjected to mechanical fatigue employing a 50N axial compression load in the center of the occlusal surface of the molars with a frequency of 2Hz (32). 1,200,000 cycles were performed, simulating 5 years of aging (27, 33).

Conversion Degree

To measure the degree of conversion of the samples (n = 5) a Fourier transformed infrared spectrometer, FTIR (Vertex 70, Bruker Optik GmbH, Ettlingen, Germany) was used. The Spectrometer has a 1.8mm diameter diamond crystal plate. First, to calibrate the FTIR a portion of unpolymerized resin was measured. The aromatic reference peak was defined in the area below 1.608 cm and the area below 1.637 as the aliphatic peak. The samples were placed on the crystal and fixed with a pressure piston to ensure adaptation. Absorbance was measured using 32 scans at 4 cm -1 resolution. A measurement was obtained in three different areas of each sample, in the mesial, occlusal and distal cases, and the three measurements were 3 mm deep in relation to the occlusal surface of each restoration.

Dissolution of unreacted monomers

To analyze the dissolution of unconverted monomers during post-photoactivated restoration, the opposite halves of the samples (n = 5) were analyzed in the FTIR. The samples were photographed on a Canon EOS camera with 100mm macro lens with standard distance and illumination. The samples were then immersed in a glass vial containing tetrahydrofuran solvent for 24 hours. The samples were then taken from the solvent and washed in running water for 1 minute. All samples were photographed again. Then the samples were immersed in 0.2g / 100ml aqueous methylene blue solution for 2 hours. The samples were washed and polished to remove surface deposition of the dye. The samples were again photographed with the same standardization. The presence of regions with evident dissolution of residual monomers were classified according to the following categories:

Level 0, there is no presence of dissolution region characterized by whitish areas nor which were later impregnated by the dye;

Level 1, minor dissolution of the restoration at the cervical margin of the restoration with margin-limited impregnation;

Level 2, moderate dissolution of the restoration penetrating beyond the cervical margin and reaching the restoration body in the proximal box;

Level 3, severe restoration dissolution reaching the axial wall and staining along the entire gingival wall.

Marginal infiltration - Scanning Electron Microscopy

After mechanical and thermal cycling, the samples (n = 5) were removed from their inclusion cylinders and had their root apex sealed with epoxy resin and the entire external surface of the teeth were covered with a cyanoacrylate layer (Superbonder, Loctite) and followed by two layers of quick-drying nail polish (Risqué, Niasi, Taboão da Serra, SP, Brazil), leaving only the 1 mm delimited area of the restoration margins in the cervical wall region of the mesial and distal proximal surfaces . The teeth were immersed in 50% aqueous AgNo3 solution and kept in a dark bottle for 6 hours. The teeth were then rinsed thoroughly in running water and dipped in developer solution (Kodak, Rochester, USA) exposed to fluorescent light for 12 hours (28, 32). Afterwards, the teeth were washed and sectioned mid-distally in the center of the restoration. The polished halves with diamond pastes (Arotec, São Paulo, Brazil) 6, 3, 1 and ¼ were washed in an ultrasonic vat for 10 minutes to remove particles formed during polishing (28). The samples were then sprayed with gold and the morphological evaluation of the resin-tooth interface on the cervical portion of the proximal boxes was conducted with SEM at various magnifications to verify the extent of silver nitrate microleakage.

Statistical analysis

The values of DC% were tested by normal distribution (Shapiro – Wilk test) and equality of variance (Levene test). 3-way analysis of variance (ANOVA) was used followed by Tukey test. All statistical tests employed a significance level of $\alpha = 0.05$. All analyzes were performed using Sigma Plot software version 13.1. Monomer dissolution and scanning electron microscopy images were quantitatively analyzed.

Results

Conversion Degree

Mean values and standard deviation of degree of conversion of all experimental conditions tested are expressed in Figure 1. ANOVA demonstrated significant effect for the triple interaction of resin type, mouth opening, and light sources (P <0.001). Tukey test showed that the DC values of restorations photoactivated with the VALO Cordless light source were not influenced by resin type or mouth opening. In addition, the restoration region factor did not determine any variation in the degree of conversion.

On the other hand, the DC values of restorations photoactivated with the radii-cal light source were influenced by the resin type (P <0.001), the mouth opening (P <0.001) and also the restoration region repetition factor (P <0.001). P <0.001). When the mouth opening factor was compared, all DC values obtained with 45mm opening were higher than 25mm, regardless of resin type and mouth opening. At the 45mm mouth opening the Opus Bulk Fill APS and Filtek Bulk Fill One resins had similar DC values, regardless of the restoration region. For the 25mm mouth opening the Opus Bulk Fill APS resin had significantly higher DC values than Filtek Bulk Fill One resin. Only for the combination of the radii-cal source in the 25 mm mouth opening the restoration region factor influenced the CD values, being the proximal values significantly lower than the occlusal box.

Characterization of tested light sources

The VALO Cordless light source features a 9.8mm internal active tip and 7.2mm radii cal. The body of the VALO Cordless appliance has a 90 ° angled active tip to the body, which is rectilinear and does not interfere with positioning in the second molar region at either the 45mm or 25mm mouth opening (Figure 4A). In the radii-cal light source, the active tip is 17 mm from the body of the device and has an angle of 45 ° to it. This makes it difficult to position the active tip in relation to the occlusal surface of the second molar at the 25mm opening (Figure 4B).

The power (mW) of the VALO Cordless light source was 613.8 □ 1.3 and radii-cal was 404.3 □ 2.3. Mean irradiance and standard deviation at the different experimental conditions measured at the deepest region of the mesial and distal proximal boxes are expressed in Table 2. The irradiance pattern and light spectrum graphs emitted during the 20 seconds of activation of the two light sources Measurements under different experimental conditions are shown in Figure 2 and 3, respectively. Much more evident reduction of the irradiance emitted for the radii-cal light source is shown when compared to VALO Cordless, regardless of the measured region, especially with the 25mm aperture. The irradiance emitted by the VALO Cordless Light source was not influenced by the mouth opening. The light spectra emitted by the VALO Cordless and radii-cal sources show that light at blue wavelength was further reduced with cavity depth. The spectrum of violet light emitted by the VALO Cordless light source was not influenced by the depth of the cavity.

Dissolution of unreacted monomers

The frequency of dissolution measured under the different experimental conditions are described in Table 3. Monomer dissolution was minimal in most samples tested from all experimental groups. There was a slight increase in dissolution for samples constructed with 25mm mouth opening and radii-cal light source, regardless of the resin tested.

Marginal Infiltration - Scanning Electron Microscopy

Silver nitrate infiltration was poorly evidenced under all experimental conditions. No significant difference was found between the experimental conditions tested.

Discussion

The objective of this work was to evaluate the relationship between light source design and mouth opening with photoactivation of bulk fill composite resins. The null hypothesis was rejected as the degree of conversion decreased in the proximal boxes and the monomer dissolution slightly increased for photoactivated samples with the 25 mm mouth-opening radii-cal light source, regardless of the resin tested.

One of the main objectives in the development of restorative materials is the search to improve their mechanical performance, increasing their clinical durability. For the composite resin to perform properly it is necessary that light penetrates its structure and photoactives the material in the deepest areas of the cavity. The light intensity decreases in proportion to the increase in the distance between resin and light source (34); Similarly, light transmission through the resin decreases exponentially with the layer thickness above 4 to 5 mm (35). Increasing the volume of restorations may increase contraction tensions, leading to cusp deflection, enamel fractures, postoperative sensitivity and microleakage. The manufacturers state that bulk fill resins have lower volumetric shrinkage, lower shrinkage stress and higher degree of conversion due to their high translucency (36). For the resin to be considered properly photoactivated it must receive adequate irradiance for sufficient exposure time, along with appropriate wavelength (37). The design of the curing light is a factor that may affect the irradiance provided to the restoration (21). The average irradiance values provided by the radii-cal in the proximal cases of the MOD cavities in the mouth opening by 25 mm were affected by the angular design of the device, which presented greater difficulty in approaching the lower second molar. This factor is one of the main aspects that justify the differences found in this study.

The degree of conversion of photoactivated composite resins directly influences their mechanical properties. To have a direct impact on the degree of conversion of a resin, the irradiance and wavelengths of the light source must match the light curing requirements prescribed by the manufacturer (38). However, the light intensity supplied decreases as the photoactivator tip moves away from the composite resin surface (39). The manufacturers recommended time for photoactivation of resins is based on laboratory work done under controlled conditions with the tip generally positioned as close to the resin as possible. However, in clinical practice this is not always possible, resulting in less radiant energy than the photoinitiator needs (40). In addition to compromising mechanical properties, insufficient photoactivation results in the release of unreacted monomers into the oral cavity and impairment of restoration longevity. One factor that certainly contributed to the performance difference between the two light sources is their design. Since the degree of resin conversion is directly related to the intensity and duration of light exposure and inversely proportional to the distance from the light source to the resin surface, the use of photoactivators such as Valo Cordless, whose straight design and 90 ° angled tip allows whereas, in addition to its introduction as close as possible to the composite resin, it provides uniform irradiance in both the mesial and distal casing, regardless of the mouth opening amplitude.

Limited mouth opening was a factor that negatively influenced the conversion of composite resins in this study. It can also be called Interincisal Distance or Correct Interincisal Distance (41). Many studies have been developed to measure the maximum healthy mouth opening (43-47). Mouth opening may vary depending on age, weight, gender (42, 43), ethnicity (44) and may be limited by dental infections, trismus, head and neck myopathy, systemic sclerosis (45) and lack of patient cooperation (46). Although male patients have a greater mouth opening amplitude in all studies, the amplitude increases significantly with age. Mean values, based on existing literature and taking into account gender and age, were defined as 45 mm for healthy adults and 25 mm for patients as pathological limitations. This justifies the values selected for this study.

In this study, two light sources with different designs were used: Valo Cordless, with an active tip at 90 with the rectilinear body of the device and a 45-degree radii-cal formed between the active tip and the light curing body and a 17 mm displacement of the active tip relative to the body of the appliance. When the radiance simulating the smallest mouth opening was evaluated, radii-cal presented smaller values independent of the measured region (Figs 2 and 3). This was due to the mispositioning of the device when it was taken into working position on the dummy, where in both 25 mm and 45 mm opening, the active tip could not be positioned close to the resin surface. At the smallest opening, the body of the appliance was locked between the second premolar and the first upper molar. Thus, the tip touched the distal cusps of the lower first molar, causing the light source to move away from the resin and the light beam to fall near 45 ° to the resin surface, reducing the irradiance in the posterior teeth (21). This leads to the formation of two shading areas in the cervical region of the proximal cases, one formed by the mesial matrix and the other by the angle formed between the pulp wall and the axial wall of the distal box. This factor explains the lower conversion rates in the proximal boxes and the slight higher monomer dissolution in this region.

To reduce unwanted effects of composites such as shrinkage stresses, some changes have been incorporated into bulk fill resins in the organic matrix, (47). Opus Bulk Fill APS composite resin had lower sensitivity than Filtek Bulk Fill One composite resin in the most extreme condition. This lower sensitivity may be due to the higher translucency presented by Opus. And it may also be associated with the presence of the Advanced Polymerization System (APS), which according to the manufacturer, is the combination of different photoinitiators that interact with each other amplifying the light curing ability even in light sources with lower wavelength or wavelength. narrower, minimizing color variation and opacity before and after curing (48).

To minimize complications such as marginal infiltration and favor greater resin conversion in difficult-to-reach situations or with less patient co-operation, the clinician should opt for rectilinear design light sources and tips with an angle closer to 90 degrees and larger in diameter. irradiance is uniformly provided on both the proximal boxes and the occlusal surface. As a suggestion for further studies, the possibility of, in addition to photoactivating the resin composed of the occlusal surface, promote additional photoactivations after removing the matrix, both by the buccal and lingual surface of each proximal box, as a way to achieve additional irradiance. in these regions so that deficiencies in the use of angled light sources can be addressed.

REFERENCES

1. Rode KM, Kawano Y, Turbino ML. Evaluation of curing light distance on resin composite microhardness and polymerization. Oper Dent. 2007;32(6):571-8. https://doi.org/10.2341/06-163

2. Par M, Gamulin O, Marovic D, Klaric E, Tarle Z. Raman spectroscopic assessment of degree of conversion of bulk-fill resin composites--changes at 24 hours post cure. Operative dentistry. 2015;40(3):E92-101. https://doi.org/10.2341/14-091-L

3. Gamarra VSS, Borges GA, Júnior LHB, Spohr AM. Marginal adaptation and microleakage of a bulk-fill composite resin photopolymerized with different techniques. Odontology. 2018;106(1):56-63. https://doi.org/10.1007/s10266-017-0294-5

4. ALShaafi MM, Haenel T, Sullivan B, Labrie D, Alqahtani MQ, Price RB. Effect of a broad-spectrum LED curing light on the Knoop microhardness of four posterior resin based composites at 2, 4 and 6-mm depths. Journal of dentistry. 2016;45:14-8. https://doi.org/10.1016/j.jdent.2015.11.004

5. Dionysopoulos D, Papadopoulos C, Koliniotou-Koumpia E. Effect of temperature, curing time, and filler composition on surface microhardness of composite resins. J Conserv Dent. 2015;18(2):114-8. https://doi.org/10.4103/0972-0707.153071

6. Ozduman ZC, Kazak M, Fildisi MA, Ozlen RH, Dalkilic E, Donmez N. Effect of Polymerization Time and Home Bleaching Agent on the Microhardness and Surface Roughness of Bulk-Fill Composites: A Scanning Electron Microscopy Study. Scanning. 2019;2019:2307305. https://doi.org/10.1155/2019/2307305

7. Carvalho AA, Moreira Fdo C, Fonseca RB, Soares CJ, Franco EB, Souza JB, et al. Effect of light sources and curing mode techniques on sorption, solubility and biaxial flexural strength of a composite resin. J Appl Oral Sci. 2012;20(2):246-52. https://doi.org/10.1590/S1678-77572012000200021

8. Kim RJ, Kim YJ, Choi NS, Lee IB. Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. J Dent. 2015;43(4):430-9. https://doi.org/10.1016/j.jdent.2015.02.002

9. Shimokawa C, Sullivan B, Turbino ML, Soares CJ, Price RB. Influence of Emission Spectrum and Irradiance on Light Curing of Resin-Based Composites. Operative dentistry. 2017;42(5):537-47. https://doi.org/10.2341/16-349-L

10. Santos GB, Medeiros IS, Fellows CE, Muench A, Braga RR. Composite depth of cure obtained with QTH and LED units assessed by microhardness and micro-Raman spectroscopy. Operative dentistry. 2007;32(1):79-83. https://doi.org/10.2341/06-26

11. Harun NA, Santini A, Roebuck EM. The effect of interincisal opening, cavity location and operator experience on the energy delivered by a light-curing unit to a simulated dental restoration. Prim Dent J. 2014;3(2):26-31. https://doi.org/10.1308/205016814812144030

12. Fatima J, Kaul R, Jain P, Saha S, Halder S, Sarkar S. Clinical Measurement of Maximum Mouth Opening in Children of Kolkata and Its Relation with Different Facial Types. Journal of clinical and diagnostic research : JCDR. 2016;10(8):Zc01-5. https://doi.org/10.7860/JCDR/2016/21232.8217

13. Mezitis M, Rallis G, Zachariades N. The normal range of mouth opening. Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons. 1989;47(10):1028-9. https://doi.org/10.1016/0278-2391(89)90174-2

14. Jiang X, Fan S, Cai B, Fang ZY, Xu LL, Liu LK. [Mandibular manipulation technique followed by exercise therapy and occlusal splint for treatment of acute anterior TMJ disk displacement without reduction]. Shanghai kou qiang yi xue = Shanghai journal of stomatology. 2016;25(5):570-3. PMID: **28116429**

15. Levorova J, Machon V, Guha A, Foltan R. Osteoarthrosis of Temporomandibular Joint Related to the Defects of Posterior Dentition: A Retrospective Study. Prague medical report. 2016;117(4):176-84. https://doi.org/10.14712/23362936.2016.18

16. de Moraes Baldrighi SEZ, Almeida LF, Alves CS, da Silva AKA, Barros Filho L, Macieira JC, et al. Amplitude máxima da abertura de boca na esclerose sistêmica. Distúrbios da Comunicação. 2016;28(1). https://revistas.pucsp.br/dic/article/view/23832

17. Abou-Atme YS, Chedid N, Melis M, Zawawi KH. Clinical measurement of normal maximum mouth opening in children. CRANIO®. 2008;26(3):191-6. https://doi.org/10.1179/crn.2008.025

18. Lewis RP, Buschang PH, Throckmorton GS. Sex differences in mandibular movements during opening and closing. American Journal of Orthodontics and Dentofacial Orthopedics. 2001;120(3):294-303. https://doi.org/10.1067/mod.2001.115612

19. Saund DSS, Pearson D, Dietrich T. Reliability and validity of self-assessment of mouth opening: a validation study. BMC oral health. 2012;12(1):48. https://doi.org/10.1186/1472-6831-12-48

20. Zawawi KH, Al-Badawi EA, Lobo SL, Melis M, Mehta NR. An index for the measurement of normal maximum mouth opening. Journal-Canadian Dental Association. 2003;69(11):737-41.

21. Soares CJ, Rodrigues MP, Oliveira LRS, Braga SSL, Barcelos LM, Silva GRD, et al. An Evaluation of the Light Output from 22 Contemporary Light Curing Units. Braz Dent J. 2017;28(3):362-71. https://doi.org/10.1590/0103-6440201601466

22. Ilie N, Luca BI. Efficacy of Modern Light Curing Units in Polymerizing Peripheral Zones in Simulated Large Bulk-fill Resin-composite Fillings. Oper Dent. 2018;43(4):416-25. https://doi.org/10.2341/17-095-L

23. Rizo E, Rodrigues M, Schliebe L, Braga S, Barcelos L, Silva G, et al. Potência Radiante, Irradiância e Espectro de Emissão de 22 Fontes de Fotoativação Utilizadas no Brasil. Journal of Health Sciences. 2018;19(5):142. https://doi.org/10.17921/2447-8938.2017v19n5p142

24. Lucey SM, Santini A, Roebuck EM. Degree of conversion of resin-based materials cured with dual-peak or single-peak LED light-curing units. Int J Paediatr Dent. 2015;25(2):93-102. https://doi.org/10.1111/ipd.12104

25. Bhatt S, Ayer CD, Price RB, Perry R. Effect of curing light and restoration location on energy delivered. Compend Contin Educ Dent. 2015;36(3):208-10, 12, 14. PMID: 25822747

26. da Silva GR, Simamoto-Junior PC, da Mota AS, Soares CJ. Mechanical properties of light-curing composites polymerized with different laboratory photo-curing units. Dent Mater J. 2007;26(2):217-23. https://doi.org/10.4012/dmj.26.217

27. Rosatto CM, Bicalho AA, Verissimo C, Braganca GF, Rodrigues MP, Tantbirojn D, et al. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. J Dent. 2015;43(12):1519-28. https://doi.org/10.1016/j.jdent.2015.09.007

28. Soares CJ, Celiberto L, Dechichi P, Fonseca RB, Martins LR. Marginal integrity and microleakage of direct and indirect composite inlays: SEM and stereomicroscopic evaluation. Braz Oral Res. 2005;19(4):295-301. https://doi.org/10.1590/S1806-83242005000400011

29. Soares CJ, Martins LR, Pfeifer JM, Giannini M. Fracture resistance of teeth restored with indirect-composite and ceramic inlay systems. Quintessence Int. 2004;35(4):281-6.

30. Braga S, Oliveira L, Ribeiro M, Vilela A, da Silva GR, Price RB, et al. Effect of Simulated Pulpal Microcirculation on Temperature When Light Curing Bulk Fill Composites. Oper Dent. 2019;44(3):289-301. https://doi.org/10.2341/17-351-L

31. Pinto JR, Mesquita MF, Henriques GE, de Arruda Nobilo MA. Effect of thermocycling on bond strength and elasticity of 4 long-term soft denture liners. J Prosthet Dent. 2002;88(5):516-21. https://doi.org/10.1067/mpr.2002.128953

32. Costa JF, Siqueira WL, Loguercio AD, Reis A, Oliveira E, Alves CM, et al. Characterization of aqueous silver nitrate solutions for leakage tests. J Appl Oral Sci. 2011;19(3):254-9. https://doi.org/10.1590/S1678-77572011000300014

33. Ornaghi BP, Meier MM, Rosa V, Cesar PF, Lohbauer U, Braga RR. Subcritical crack growth and in vitro lifetime prediction of resin composites with different filler distributions. Dent Mater. 2012;28(9):985-95. https://doi.org/10.1016/j.dental.2012.05.001

34. Ilie N, Kessler A, Durner J. Influence of various irradiation processes on the mechanical properties and polymerisation kinetics of bulk-fill resin based composites. J Dent. 2013;41(8):695-702. https://doi.org/10.1016/j.jdent.2013.05.008

35. Ilie N. Impact of light transmittance mode on polymerisation kinetics in bulk-fill resin-based composites. J Dent. 2017;63:51-9. https://doi.org/10.1016/j.jdent.2017.05.017

36. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LE, Martin AA, et al. Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. Dent Mater. 2015;31(12):1542-51. https://doi.org/10.1016/j.dental.2015.10.001

37. Price RB, Labrie D, Rueggeberg FA, Felix CM. Irradiance differences in the violet (405 nm) and blue (460 nm) spectral ranges among dental light-curing units. J Esthet Restor Dent. 2010;22(6):363-77. https://doi.org/10.1111/j.1708-8240.2010.00368.x

38. Daugherty MM, Lien W, Mansell MR, Risk DL, Savett DA, Vandewalle KS. Effect of high-intensity curing lights on the polymerization of bulk-fill composites. Dent Mater. 2018;34(10):1531-41. https://doi.org/10.1016/j.dental.2018.06.005

39. Pires JA, Cvitko E, Denehy GE, Swift EJ, Jr. Effects of curing tip distance on light intensity and composite resin microhardness. Quintessence Int. 1993;24(7):517-21. PMID: **8210323**

40. Al-Zain AO, Eckert GJ, Platt JA. The Influence of Distance on Radiant Exposure and Degree of Conversion Using Different Light-Emitting-Diode Curing Units. Oper Dent. 2019;44(3):E133-E44. https://doi.org/10.2341/18-004-L

41. Zawawi KH, Al-Badawi EA, Lobo SL, Melis M, Mehta NR. An index for the measurement of normal maximum mouth opening. J Can Dent Assoc. 2003;69(11):737-41.

42. Abou-Atme YS, Chedid N, Melis M, Zawawi KH. Clinical measurement of normal maximum mouth opening in children. Cranio. 2008;26(3):191-6. https://doi.org/10.1179/crn.2008.025

43. Lewis RP, Buschang PH, Throckmorton GS. Sex differences in mandibular movements during opening and closing. Am J Orthod Dentofacial Orthop. 2001;120(3):294-303. https://doi.org/10.1067/mod.2001.115612

44. Gallagher C, Gallagher V, Whelton H, Cronin M. The normal range of mouth opening in an Irish population. Journal of oral rehabilitation. 2004;31(2):110-6. https://doi.org/10.1046/j.0305-182X.2003.01209.x

45. Kumar A, Dutta S, Singh J, Mehta R, Hooda A, Namdev R. Clinical measurement of maximal mouth opening in children: a pioneer method. J Clin Pediatr Dent. 2012;37(2):171-5. https://doi.org/10.17796/jcpd.37.2.l17x8227682j5610

46. Soares CJ, Braganca GF, Pereira R, Rodrigues MP, Braga SSL, Oliveira LRS, et al. Irradiance and Radiant Exposures Delivered by LED Light-Curing Units Used by a Left and Right-Handed Operator. Braz Dent J. 2018;29(3):282-9. https://doi.org/10.1590/0103-6440201802127

47. Lins RBE, Aristilde S, Osorio JH, Cordeiro CMB, Yanikian CRF, Bicalho AA, et al. Biomechanical behaviour of bulk-fill resin composites in class II restorations. J Mech Behav Biomed Mater. 2019;98:255-61. https://doi.org/10.1016/j.jmbbm.2019.06.032

48. FGM. Manual Opus Bulk Fill APS 2019 https://www.fgm.ind.br/wp-content/uploads/2019/06/Manual-opus_bulk_fill.pdf

.

ANEXOS

Table 1. Characteristics of the composite resins used in this study.

Material	Code	Composite Resin Type	Organic Matrix	Charge particles	Percentage charge/ volume	Manufacturer
Filtek Bulll Fill One	One	Regular Viscosity Bulk Fill	UDMA, Bis-EMA, BisGMA, TEGDMA ethyl 4dimethylaminobenzoate	treated silanized ceramics, ytterbium fluoride	50/60	3M ESPE (St Paul, MN, USA)
OPUS Bulk Fill APS	OPUS	Regular Viscosity Bulk Fill	TEGDMA, Bis- EMA, UDMA	Silica with urethane dimethacrylate, salinized silica dioxide, salinized barium glass, YbF3	68/79	FGM

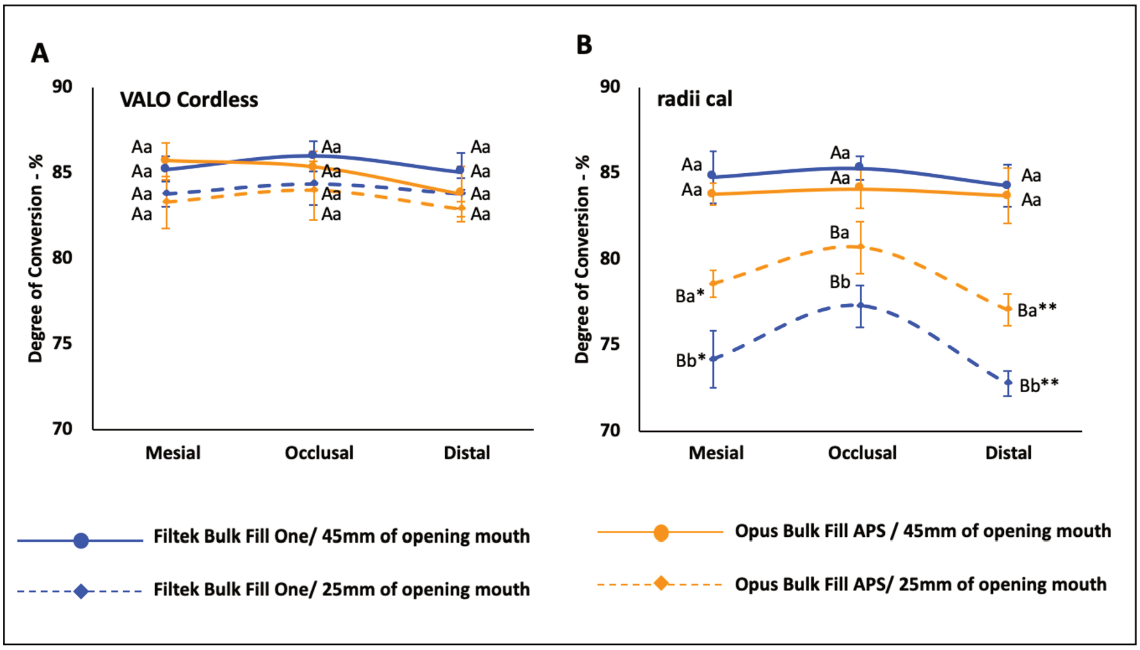

Figure 1. Mean values and standard deviation of the degree of conversion measured at mesial, occlusal and distal as a function of Filtek Bulk Fill One and

Opus Bulk Fill APS resins, photoactive with the VALO Cordless and radii cal light sources with the mouth opening. 25 and 45mm. Different letters and symbols express significant differences. Capital letters used to compare the mouth opening factor; lower case letters used to compare composite resins; * used to compare region within the same restoration.

Table 2. Mean value and standard deviation of the measured irradiance at the active tip outlet of the light sources tested and at the maximum depth in the proximal boxes with the mouth opening of 25 and 45mm.

Light Source	**0mm**	**25mm**		**45mm**	
		Mesial	**Distal**	**Mesial**	**Distal**
VALO Cordless	1295,8 ± 2,7	943,3 ± 6,5	823,7 ± 1,8	937,4 ± 3,7	818,1 ± 2,4
radii-cal	1132,5 ± 10,0	268,8 ± 2,5	269,4 ± 2,0	408,6 ± 16,7	453,3 ± 1,8

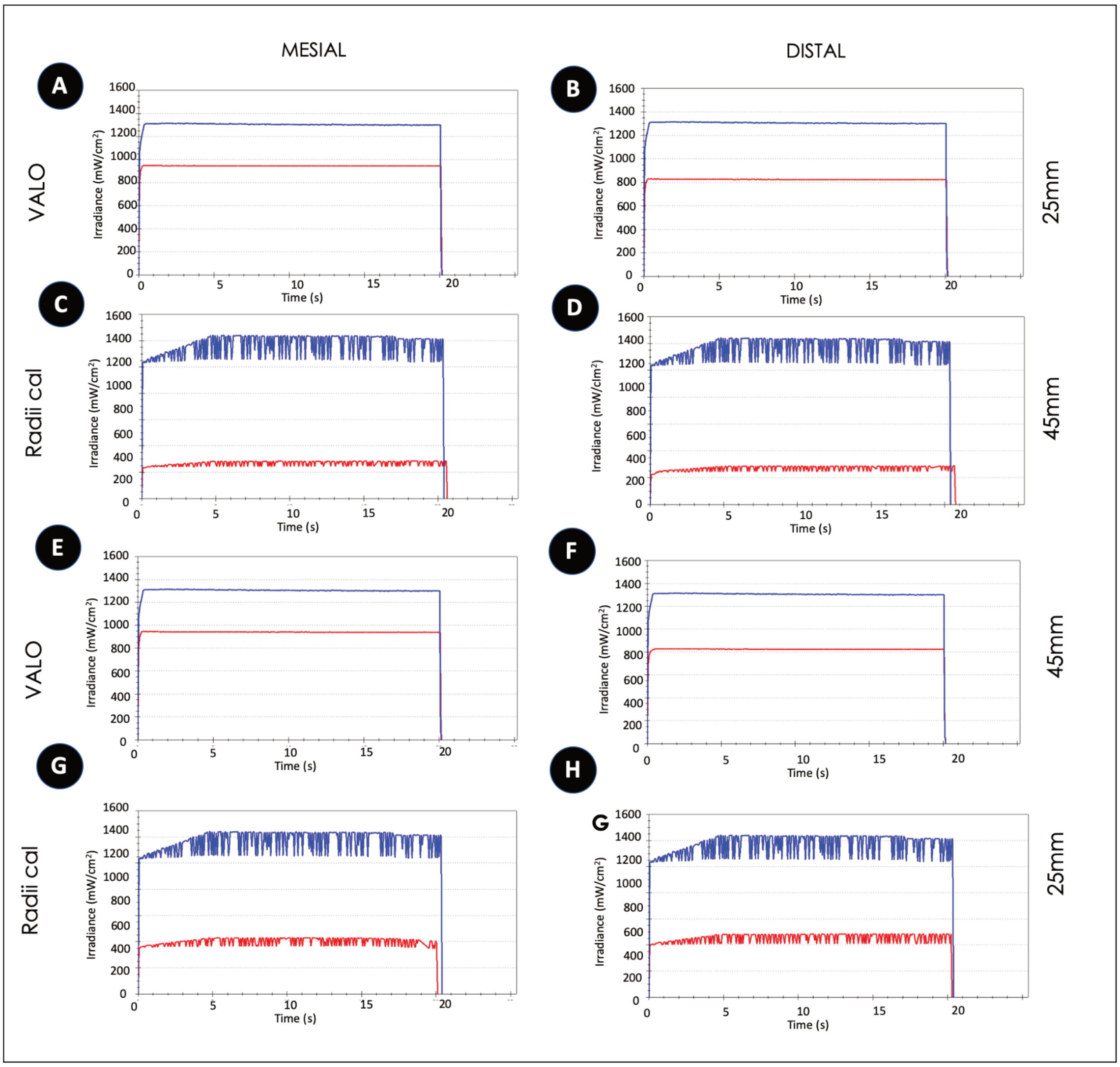

Figure 2. Representative graphs of the measured irradiance at the base of the mesial and distal cavity compared to the maximum irradiance emitted by VALO Cordless and radii cal light sources with the mouth opening 25 and 45mm.

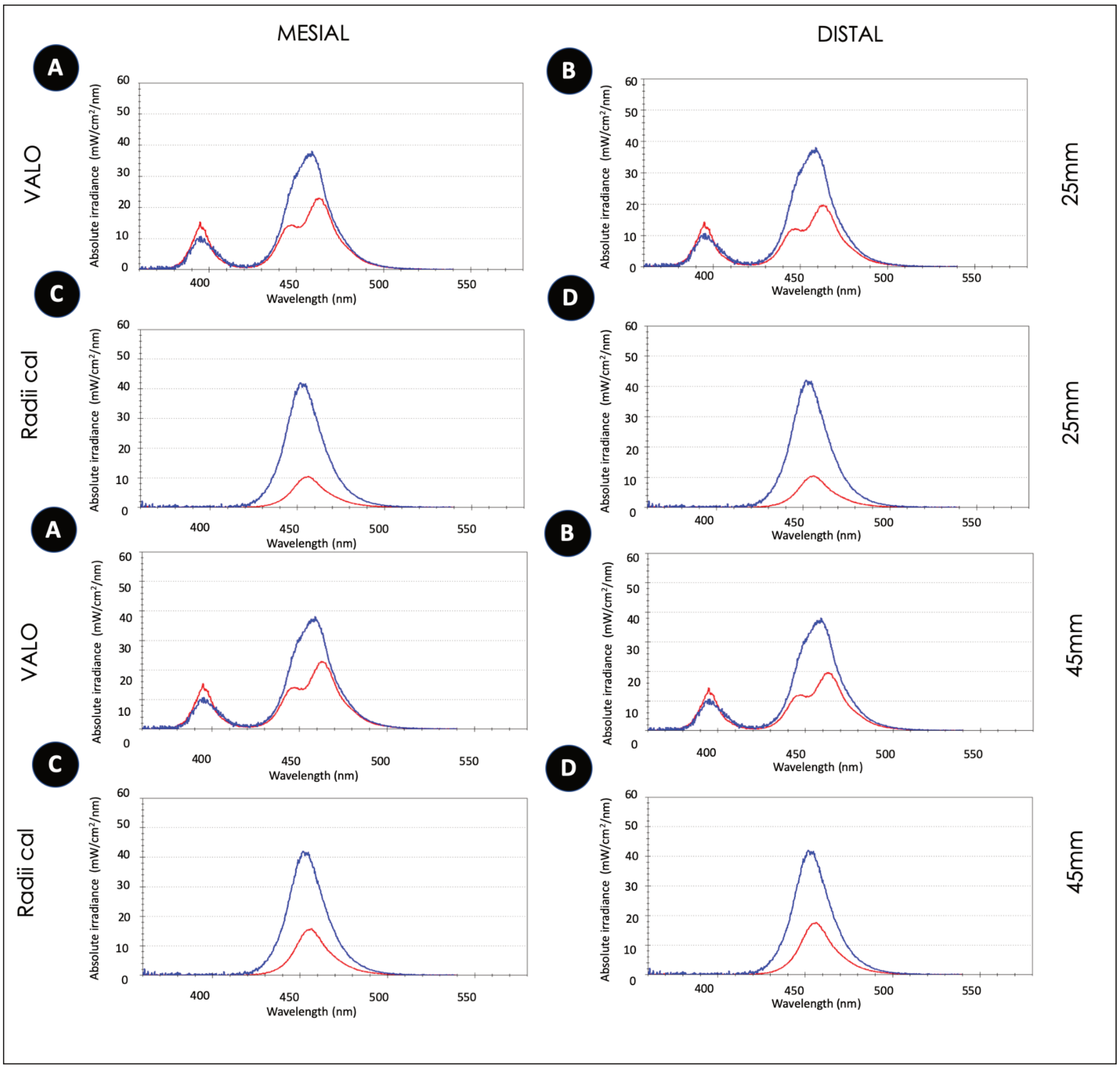

Figure 3. Representative graphs of the representative light spectrum measured at the base of the mesial and distal cavity compared to the maximum irradiance emitted by the VALO Cordless and radii cal light sources with the mouth opening 25 and 45mm.

Figure 4. A. VALO Cordless light source (Ultradent, South Jordan, UT, USA), with its straight design and active tip at 90 ° to body, demonstrating

Table 3. Frequency of dissolution and dye impregnation in proximal boxes with 25 and 45mm mouth openings for bulk fill resins and light sources tested.

Light Source		Degree of dissolution of monomers	25mm		45mm	
			Mesial	**Distal**	**Mesial**	**Distal**
Valo Cordless	Filtek Bulk Fill One	**0**	1	3	2	2
		1	3	2	2	2
		2	1	0	1	1
		3	0	0	0	0
	Opus Bulk fill APS	**0**	4	3	3	3
		1	1	2	1	2
		2	0	0	1	0
		3	0	0	0	0
radii-cal	Filtek Bulk Fill One	**0**	1	1	3	2
		1	1	2	2	2
		2	3	2	0	1
		3	0	0	0	0
	Opus Bulk fill APS	**0**	1	2	3	2
		1	3	2	1	2
		2	1	1	1	1
		3	0	0	0	0