UNIVERSIDADE FEDERAL DE UBERLÂNDIA

FACULDADE DE ODONTOLOGIA

LUÍSA DE OLIVEIRA FERNANDES

INFLUÊNCIA DO DIÂMETRO DA PONTA E DO ESPECTRO DE LUZ DE APARELHOS FOTOATIVADORES NAS PROPRIEDADES DE RESINAS BULK-FILL

UBERLÂNDIA

2022

LUÍSA DE OLIVEIRA FERNANDES

INFLUÊNCIA DO DIÂMETRO DA PONTA E DO ESPECTRO DE LUZ DE APARELHOS FOTOATIVADORES NAS PROPRIEDADES DE RESINAS BULK-FILL

Trabalho de Conclusão de Curso apresentado a Faculdade de Odontologia da UFU, como requisito parcial para obtenção do título de Graduado em Odontologia

Orientador: Prof. Dr. Luís Henrique Araújo Raposo

Co-orientador: Me. Igor Oliveiros Cardoso

UBERLÂNDIA

2022

Agradecimentos

A vida é feita de objetivos que trabalhamos para alcançar, e este Trabalho de Conclusão de Curso é a representação de um dever cumprido. Agradeço primeiramente à Deus e à Nossa Senhora Aparecida por terem guiado meus passos até aqui, mesmo nos dias mais difíceis e desafiadores, me reerguendo e me dando forças para continuar em meu propósito. Agradeço aos meus pais, Márcia e Gilmar, por nunca medirem esforços para que eu conquistasse mais esse sonho, sempre com muito companheirismo e carinho, sem eles nada seria possível. Agradeço a minha irmã Leandra, que com seu jeito único e especial sempre me apoiou e me amparou mesmo a quilômetros de distância. Agradeço também ao meu noivo Gabriel por sempre entender minhas ausências, meus momentos de dedicação e principalmente me apoiar em cada ocasião que precisei de seu companheirismo. Agradeço aos meus tios, Tânia e Rafael, por me acolherem e me ensinarem o caminho da Odontologia, o qual me apaixonei desde muito pequena e principalmente por servirem de inspiração sempre. Agradeço ainda a todos os meus amigos da faculdade e fora dela, mas em especial à minha grande dupla de clínica Maria Tereza que me ajuda e me entende pelo olhar sempre que preciso. Sou grata pela nossa conexão. Agradeço também pela orientação dos meus professores Luís Raposo, Paulo Vinícius e Igor Oliveiros, pela oportunidade e instrução ao longo destes anos de iniciação científica. E por fim, e não menos importante, agradeço a uma pessoa muito especial que comemorou comigo desde o momento da aprovação, se orgulhou da primeira vez em que vesti branco, e tenho certeza que se orgulha de onde estiver de mais essa conquista: minha querida avó Lázara.

SUMÁRIO

Abstract

Objective: The aim of this study was to evaluate the influence of different light-curing units (LCUs) with distinct tip diameters and light spectra for activating bulk-fill resins.

Materials and methods: The specimens (n=10) were made from a conventional composite (Amaris, VOCO) and bulk-fill resins (Aura Bulk Fill, SDI; Filtek One, 3M ESPE; Tetric Bulk Fill, Ivoclar Vivadent) with two diameters, 7 or 10 mm, x 2 mm thickness. Following 24 h of specimen preparation, the degree of conversion (DC) was evaluated using the FTIR unit. Knoop microhardness (KHN) readings were performed on the center and periphery of the specimens. Data were assessed for homoscedasticity and submitted to 1-way and 3-way analysis of variance followed by the Tukey and Dunnett tests, depending on the analysis performed ($\alpha=0.05$).

Results: LCUs and specimen diameter significantly affected the DC. The *Tetric Bulk Fill* provided increased DC results when light-cured with *Valo* (54.8 and 53.5%, for 7 and 10 mm, respectively) compared to *Radii Xpert* (52.1 and 52.9%, for 7 and 10 mm, respectively). No significant differences in KHN results were noted for the conventional resin composite (*Amaris*) compared with LCUs ($p=0.213$) or disc diameters ($p=0.587$), but the center of the specimen exhibited superior KHN ($p\leq0.001$) than the periphery.

Conclusion: The light spectrum of the multipeak LCU (*Valo*) significantly increased the DC and KHN of the bulk-fill resin composite with additional initiator to CQ (*Tetric Bulk Fill*) compared to the monowave LCU (*Radii Xpert*). The tip size of the LCUs influenced the performance of some of the resin composites tested.

Keywords: composite resins, light curing, polymerization

Introduction

Resin-based composites (RBCs) are widely used materials for Class I and II restorations with failure rates of 1.8% after 5 years and 2.4% after 10 years.[1] Although conventional RBCs exhibit good mechanical properties, they also present undesirable characteristics, such as polymerization shrinkage.[2] This shrinkage results in residual stress in the tooth-restoration interface. If not controlled or reduced either by the operator or material, the shrinkage stress is related to marginal staining, enamel cracks and postoperative sensitivity.[2] According to the World Dental Federation, direct restorations can fail based on aesthetic, functional or biological aspects.[3] Shrinkage stress may be related with all these criteria regardless of whether manifested early or in late stages, leading to failures.[3] Some measures can be taken to reduce the influence of polymerization shrinkage; for example, the use of incremental insertion techniques or bulk-fill composite materials would be beneficial for the final restoration.[4] Beyond decreasing the clinical time of the restorative procedure, bulk-fill resin composites are used in single increments of up to 4 or 5 mm thickness because they present lower polymerization shrinkage and consequently lower residual shrinkage stress.[5]

For RBCs restorations to be successful and acquire adequate mechanical and optical properties, proper polymerization is require.[6] Some relevant properties for the success of a restoration, such as the degree of conversion and hardness, are influenced by irradiance and the light spectrum.[6,7] The degree of conversion, namely, monomers converting to polymers, is directly related to hardness, a property that expresses the mechanical and wear resistance of resin-based composites.[5,7] The light-curing unit (LCU) provides the light that will allow the activation of initiators present in the composites to trigger the polymerization process.[7] Currently, the most widely used LCUs include light emitting diodes (LED) that can present different spectra, and these devices are classified into monowave and multipeak units.[8] Monowave LED units present a light spectrum between 450 and 490 nm. This light spectrum is effective in activating the camphorquinone (CQ) initiator, which has its peak action at 468 nm and is the most commonly used agent in resin-based materials.[9] Multipeak LED units present violet light in addition to blue light with emission of wavelengths below 420 nm, allowing the activation of different initiators.[9]

The light tips of the LCUs have different diameters,[10] and their sizes often do not coincide with the mesio-distal distances of the posterior teeth, which ranges from 6.74 to 7.16 mm in premolars and from 9.72 to 11.03 mm in molars.[11] For the incremental technique, this factor may not be relevant given that each increment must be individually activated by light. However, for the use of bulk-fill resins, only one light-activation cycle is typically performed. Under these circumstances, the mesio-distal distance from the teeth and the diameter of the LED tip must be known to perform proper light-curing to the whole restoration and consequently allow for sufficient polymerization.[12] LCUs with small tip diameter used to activate large molar restorations may not completely cover the resin composite, potentially resulting in insufficient polymerization.[7]

Thus, the aim of this study was to evaluate the influence of different LED-based LCUs with different tip diameters and light spectra for activating bulk-fill RBCs. The null-hypothesis generated was that LCUs with different tip sizes and light spectra would not influence the degree of conversion and Knoop hardness of different bulk-fill RBCs.

Methods and materials

Irradiance Measurement

The curing units, Valo (Ultradent, Salt Lake City, UT, USA) and Radii Xpert (SDI, Bayswater, Australia) were fully charged as recommended by the manufacturer. The higher power (mW) of the cordless LED units during the cycle was individually checked for 5 light cycles of 20s using a power meter (Nova, Ophir Spiricon, Logan, UT, USA), then the average of the 5 cycles was divided by the tip area (cm^2), calculated from the optical diameter, as measured with a digital caliper (CD6CS, Mitutoyo, Kanagawa, Japan), to obtain the irradiance (mW/cm2) (Table 1).[13]

Specimen preparation

To simulate the diameter of average occlusal cavities in premolars and molars, 2-mm thick resin cylinders with 7 mm and 10 mm diameter, respectively, were made from the conventional and bulk-fill composites as described in Table 2. For this, circular aluminum matrixes were positioned over glass plates, and specimens were obtained by inserting the RBCs in a single increment. Then, a Mylar strip and a glass plate were placed over the resin and slightly compressed to regularize the top surface of the specimens.

For light curing the specimens, the tip of the LCU (Table 1) was positioned parallel and in close contact to the top glass plate, and light-curing was performed for 20s, as recommended by each composite manufacturer, using a standardized position. The position of each specimen in relation to the LCU tip was noted in the top of the discs with permanent marker to allow the same position to be determined during the tests. After this, the specimens were stored under dry conditions in identified light-proof containers.

Degree of conversion (DC)

Twenty-four hours after specimen preparation, the DC was evaluated at the center of the top surface of the specimens (n=10) using Attenuated Total Reflectance (ATR) Fourier-transform infrared spectroscopy (FTIR) unit (Tensor 27, Bruker, Ettlingen, Germany). To determine the number of carbon bonds remaining, a percentage was obtained between the aliphatic C=C (vinyl) (1638 cm^{-1}) and aromatic C=C absorption (1608 cm^{-1}) chains for both cured and uncured specimens. The spectra of cured and uncured specimens were obtained using 32 scans at 4 cm^{-1} resolution within 1000 to 6000 cm^{-1} range. The spectra were subtracted from the background spectra using the FTIR unit provided software (OMNIC 6.1, Nicolet 138 Instrument Corp, Madison, WI, USA). The DC was calculated with the following equation: DC (%) = [1- (cured aliphatic / aromatic ratio) / (uncured aliphatic / 144 aromatic ratio)] x 100.[6]

Knoop microhardness (KHN)

KHN specimens were included in polyester resin to allow for better handling during polishing and hardness tests. Then, the specimens were submitted to sequential wet polishing using sandpapers (#100, 600, 1200, 2000 and 3000 grit; 3M, Sumaré, SP, Brazil) in an automatized polisher for 1 min in each polisher. Sequentially, the specimens received final polishing using felt discs associated with 1 µm and 0.25 µm metallographic diamond pastes (Arotec, Cotia, SP, Brazil) for 1 min in each polisher. The specimens were then washed with deionized water.

After air-drying, the specimens were submitted to KHN tests (HMV-2; Shimadzu, Kyoto, Japan), which were performed on the top surface by applying a load of 100 g for 10 s. Fifteen indentations were performed in each specimen at five different areas with 3 indentations in the central area and 12 in the periphery with 3 in each extremity: superior, inferior, left and right, 1 mm away from the margin of the disc. The KHN corresponding to each indentation was determined by measuring the dimensions of the indentation using the following formula: *KHN = 14.2 (F=d/d2)*, where *F* is the test load in Kg, and *d* is the longer diagonal length of an indentation in mm. Then, the KHN value was determined by obtaining the arithmetic mean of indentations made in the center and peripheries.[5]

Statistical analysis

The data collected for DC and KHN were assessed for homoscedasticity and submitted to 3-way ANOVA. Multiple comparisons were made using the Tukey test within the experimental groups. One-way ANOVA followed by Dunnett test was used for comparisons between control and experimental groups. All the tests were conducted at a $\alpha = 0.05$ significance level. The analyses were performed using a statistical software (SigmaPlot 12.0, Systat Software, San Jose, CA, USA).

Results

Degree of conversion (DC)

The DC results are shown in Tables 3 and 4. *Tetric Bulk Fill* exhibited increased DC compared to conventional resin composite for both diameters and LCUs evaluated. For *Filtek One*, significant differences from the control group were only observed for 10-mm specimens light-cured with *Radii Xpert*, which presented increased DC. *Aura Bulk Fill* exhibited increased DC compared with the control group in almost conditions. However, no significant differences were verified for 10-mm specimens light-cured with *Valo*. None of the bulk-fill RBCs exhibited significantly reduced DC results compared to the control group. In most situations, bulk-fill RBCs exhibited superior or statistically similar DC results (Table 3).

LCUs and specimen diameter significantly affected DC results compared with bulk-fill RBCs (Table 4). The *Tetric Bulk Fill* showed increased DC results (54.8 and 53.5% for 7 mm and 10 mm, respectively) when light cured with *Valo* compared to *Radii Xpert* (52.1 and 52.9%, respectively). When using *Valo*, *Tetric Bulk Fill* also presented superior DC results compared with the other bulk-fill RBCs evaluated. The *Tetric Bulk Fill* and *Aura Bulk Fill* presented superior DC results compared with *Filtek One* when light curing with *Radii Xpert*. Significant differences were observed for DC results for the different specimen diameters in the *Filtek One* group.

Knoop Microhardness (KHN)

The KHN results are described in Tables 5 and 6. No significant differences were noted in KHN results for the conventional resin composite (*Amaris*) when comparing LCUs (p=0.213) or disc diameters (p=0.587), but the center of the specimen exhibited superior KHN (p≤0.001) compared with periphery. KHN results for *Aura Bulk Fill* were not influenced by LCUs (p=0.049), specimen diameter (p=0.468) or region of analysis (p=0.083). For *Filtek On*e, similar KHN results were verified for the different LCUs (p=0.276), but 7-mm diameter specimens exhibited greater KHN than 10 mm (p=0.002), and the center region exhibited superior results compared to periphery (p=0.038). For *Tetric Bulk Fill*, light curing with *Valo* resulted in superior KHN compared to *Radii Xpert* (p≤0.001), and 7-mm specimens also presented increased KHN compared with 10-mm diameter specimens (p=0.015), but no significant differences were observed for the region of analysis.

None of the experimental groups showed significantly reduced KHN results compared to the control group (Amaris). The 7-mm *Aura Bulk Fill* specimens photoactivated with *Valo* were not statistically different compared with *Amaris* (control group). All other groups presented significantly superior KHN results compared with the control group (Table 5).

Discussion

The LCUs tested in the present study present different tip diameters and light spectra and have influenced the degree of conversion and Knoop hardness of the bulk-fill RBCs tested. Thus, the null hypothesis tested was rejected.

The use of bulk-fill RBCs have increased substantially in recent years, and adequate light curing is essential to achieve the best mechanical properties with these materials.[7] The polymerization process of light-cured composites is completely dependent on the technical characteristics of the LCU, such as irradiance, wave length range, diameter of the tip, and others.[14] Different LCUs can result in distinct physical properties for the same material given that the degree of conversion and hardness of RBCs may be affected as demonstrated by the results of this investigation and previous studies.[15,16] _ENREF_21

Different mechanisms can be used to allow deeper polymerization and reduced stress for bulk-fill composites. Some manufacturers achieve deeper polymerization by using additional or different photoinitiators, such as diphenyl phosphine oxide (Lucerin – TPO) or bis-(4-methoxybenzoyl)diethyl-germane (Ivocerin).[17] The properties of bulk-fill resins may also be improved when increased light transmission through the composite is possible, which its commonly achieved by changing the filler content. The presence of pigments and refractive index mismatch between the organic matrix and fillers are the main factors causing reduction in light transmission.[18]

In the present study, no bulk-fill RBCs presented lower DC values than the conventional composite (control group). The LCU factor was only relevant for *Tetric N-Ceram Bulk Fill*, and this may be explained by the fact that this material has an additional initiator to CQ, Ivocerin, which is most reactive at 408 nm but remains sensitive to wavelengths between 400-430 nm.[19] This spectrum of light is present in *Multipeak* LCUs with wavelength peaks at 405 nm, 440 nm and 460 nm but not in the *Monowave* LCUs, which commonly present a wavelength peak approximately 460 nm.[20] For the other bulk-fill RBCs in which the manufacturer does not mention the initiator used or only CQ is present, the light spectrum emitted from the *Monowave* LCU was sufficient to achieve similar DC to that obtained with the *Multipeak* LCU. The manufacturers of the bulk-fill RBCs used in this study do not completely indicate the specific initiators and the number of initiators used in these materials. The limitation of this test was that the size of the FTIR reading platform only allowed readings to be performed in the center of the specimens, and it was not possible to analyze the DC in peripheral areas.

The hardness of dental materials is an important aspect for the selection of different restorative approaches on posterior teeth.[5] In the present study, no bulk-fill RBCs presented lower KHN values than the convectional composite tested. Only *Aura Bulk Fill* 7-mm specimens light-cured by *Valo* exhibited similar KHN results to the control group, and the other experimental groups exhibited superior KHN in all conditions evaluated. *Filtek One* exhibited higher KHN results compared with the other RBCs, and a possible explanation may be the different monomers and filler composition present in this material (Table 1). Regarding the degree of conversion, LCU was the only relevant factor for the *Tetric N-Ceram Bulk Fill* groups.

There is a high demand for Class II restorations, which have an annual failure rate of 1.68% over 12 years.[21] Conventional and bulk-fill RBCs are suitable materials for these restorations.[14,15,22] Clinically, several LCUs present smaller tips compared with the restorative area that needs to be reached by light (10). Mesio-occluso-distal (MOD) cavities, such as those noted in first maxillary molars with a 10.31-mm mean mesio-distal distance (MD-D); second maxillary molars (9.79 mm MD-D), and first (6.98 mm MD-D) or second maxillary premolars (6.74 mm MD-D) may present superior dimensions compared with the LCU tip.[11] Thus, the specimens in this study exhibited two different diameters: 7 mm (equivalent to maxillary premolars MD-D) and 10 mm (equivalent to maxillary molars MD-D).

The conventional composite *Amaris* and the *Filtek One* bulk-fill exhibited variations in KHN, which were verified at the central and peripheric regions of the specimens. KHN measurements were performed at the top of the specimens given that the main objective was to verify the influence of the LCU tip diameter and not the polymerization depth. The central region of the *Amaris* and *Filtek One* specimens exhibited increased KHN values compared with the periphery. These results are consistent with previous studies that reported similar findings.[7,23] The *Tetric N-Ceram* and *Aura* bulk-fill RBCs presented similar hardness values at the center and periphery. This fact can be justified by the composition of the organic matrix in these composites that allows greater dispersion of light or the presence of additional initiators that may consequently lead to favorable physical properties in the periphery.[24,25]

The *Valo* LCU has 4 LEDs positioned in the different quarters of the tip diameter, which results in a nonuniform wavelength light beam emission because 3 LEDs emits blue light (2 with peak emission at 460 nm and 1 with at 440 nm) and 1 LED emits violet light (peak emission at 405 nm).[20] Despite this fact, no differences in KHN were assessed in the center or periphery of the specimens for the bulk-fill resin composite with the additional initiator (Ivocerin). This finding indicates that the rotation angle of the light tip from multipeak LCUs may not affect the properties of RBCs with different photoinitiators from CQ. The KHN test was performed at the top of the specimens in order to analyze the possibilities of using bulk-fill composited in wide cavities, allowing a single increment to be used in such situations. This is important, since in the incremental technique it should be avoided joining antagonistic walls in one increment, such as buccal with lingual and mesial with distal walls.[26]

LCUs with small-diameter tips should not be an issue if an incremental filling technique is used.[7] However, reduced light tips may become a problem when a bulk technique is used for extensive MOD restorations. Additional light exposure in the peripheric regions of MOD and larger cavities in posterior teeth is subsequently recommended.[23] Thus, clinicians can assure that all bulk fill-resins receive proper light irradiance, even when using LCUs with small tips. To minimize this problem, additional light exposure in the mesial and distal regions is suggested. LCUs with wide tips and longer exposure times are preferred when light-curing MOD or other large restorations.[23]

Despite the limitations of mechanical laboratory tests, they can provide better understanding of fragile materials that are more likely to fail early as RBCs.[27] The light beam profile provides information on the irradiance distribution from LCUs,[8] and the light emitted from LCUs influences the polymerization of light-cured RBCs and consequently its properties.[6] Several LCUs present very irregular beam profiles with very high irradiance values at the center of the tip and low values or even no irradiance at the periphery. Thus, the effective light-curing area can be even smaller than the tip of the device.[8,23] Despite this, the mold and the diameter used for preparing the specimens can influence the degree of conversion of the composites. As one of the factors analyzed in this study was the restoration dimension (specimen diameter), it was not possible to standardize the diameter between specimens.[28]

The distance from the tip of the LCU to the restoration can also influence the irradiance reaching the material and consequently its physical properties.[29] In this study, tests were performed with the LCU in close contact to the RBCs. This condition represent the ideal condition, but there are clinical situations in which it is not possible to place the LCU tip in close contact to the restoration, such as in deep cavities larger than 5 mm and proximal regions with adjacent teeth.[30] In addition LCUs are generally poorly maintained in dental offices and can deliver inadequate light output.[6] This is a limitation of the present study, as light was always delivered from a favorable position and the LCUs were maintained in ideal conditions.

Therefore, clinicians should be aware that the properties of the restoration are material dependent, and bulk-fill RBCs available on the market may present very distinct physical properties. In addition, is also important to distinguish the initiators present in the resin composites that are used in routine practice and the emission spectrum of the LCU given that these aspects are important to achieve adequate mechanical properties for RBCs. Unfortunately, some manufacturers do not provide this information. Studies are necessary to further investigate the relationship between the tip diameter of LCUs and the properties of RBCs.

Conclusion

Within the limitations of the present study, it was possible to observe that the light spectrum of the multipeak LCU significantly increased the DC and KHN of a bulk-fill resin composite with additional initiator to CQ, compared to the monowave LCU. LCU tip size influenced the performance of some RBCs tested. The influence of LCU on the properties of RBCs is material dependent.

References

1. Opdam NJ, van de Sande FH, Bronkhorst E, et al. Longevity of posterior composite restorations: a systematic review and meta-analysis. J Dent Res 2014;93(10):943-9.
2. Mantri SP, Mantri SS. Management of shrinkage stresses in direct restorative light-cured composites: a review. J Esthet Restor Dent 2013;25(5):305-13.
3. Hickel R, Roulet JF, Bayne S, et al. Recommendations for conducting controlled clinical studies of dental restorative materials. Clin Oral Investig 2007;11(1):5-33.
4. Veloso SRM, Lemos CAA, de Moraes SLD, et al. Clinical performance of bulk-fill and conventional resin composite restorations in posterior teeth: a systematic review and meta-analysis. Clin Oral Investig 2019;23(1):221-33.
5. Cerda-Rizo ER, de Paula Rodrigues M, Vilela A, et al. Bonding Interaction and Shrinkage Stress of Low-viscosity Bulk Fill Resin Composites With High-viscosity Bulk Fill or Conventional Resin Composites. Oper Dent 2019;44(6):625-36.
6. Pereira AG, Raposo L, Teixeira D, et al. Influence of Battery Level of a Cordless LED Unit on the Properties of a Nanofilled Composite Resin. Oper Dent 2016;41(4):409-16.
7. Shimokawa CAK, Turbino ML, Giannini M, Braga RR, Price RB. Effect of light curing units on the polymerization of bulk fill resin-based composites. Dent Mater 2018;34(8):1211-21.
8. Price RB, Labrie D, Rueggeberg FA, et al. Correlation between the beam profile from a curing light and the microhardness of four resins. Dent Mater 2014;30(12):1345-57.
9. Sahadi BO, Price RB, Andre CB, et al. Multiple-peak and single-peak dental curing lights comparison on the wear resistance of bulk-fill composites. Braz Oral Res 2018;32:e122.
10. Soares CJ, Rodrigues MP, Oliveira LRS, et al. An Evaluation of the Light Output from 22 Contemporary Light Curing Units. Braz Dent J 2017;28(3):362-71.
11. Lombardo L, Marcon M, Arveda N, et al. Preliminary biometric analysis of mesiodistal tooth dimensions in subjects with normal occlusion. Am J Orthod Dentofacial Orthop 2016;150(1):105-15.
12. Merz ML, Isaacson RJ, Germane N, Rubenstein LK. Tooth diameters and arch perimeters in a black and a white population. Am J Orthod Dentofacial Orthop 1991;100(1):53-8.

13. Shimokawa CA, Turbino ML, Harlow JE, Price HL, Price RB. Light output from six battery operated dental curing lights. Mater Sci Eng C Mater Biol Appl. 2016 Dec 1;69:1036-42.
14. Cardoso IO, Machado AC, Teixeira D, et al. Influence of Different Cordless Light-emitting-diode Units and Battery Levels on Chemical, Mechanical, and Physical Properties of Composite Resin. Oper Dent 2019.
15. Pirmoradian M, Hooshmand T, Jafari-Semnani S, Fadavi F. Degree of conversion and microhardness of bulk-fill dental composites polymerized by LED and QTH light curing units. J Oral Biosci 2020;62(1):107-13.
16. 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.
17. Menees TS, Lin CP, Kojic DD, Burgess JO, Lawson NC. Depth of cure of bulk fill composites with monowave and polywave curing lights. Am J Dent 2015;28(6):357-61.
18. Shortall AC, Palin WM, Burtscher P. Refractive index mismatch and monomer reactivity influence composite curing depth. J Dent Res 2008;87(1):84-8.
19. Sampaio CS, Pizarro PG, Atria PJ, et al. Effect of Shortened Light-Curing Modes on Bulk-Fill Resin Composites. Oper Dent 2020.
20. de Oliveira D, Rocha MG, Correr AB, Ferracane JL, Sinhoreti M. Effect of Beam Profiles From Different Light Emission Tip Types of Multiwave Light-emitting Diodes on the Curing Profile of Resin-based Composites. Oper Dent 2019;44(4):365-78.
21. Opdam NJ, Bronkhorst EM, Loomans BA, Huysmans MC. 12-year survival of composite vs. amalgam restorations. J Dent Res 2010;89(10):1063-7.
22. Durão MA, Andrade AKM, Santos MDCMDS, Montes MAJR, Monteiro GQM. Clinical Performance of Bulk-Fill Resin Composite Restorations Using the United States Public Health Service and Federation Dentaire Internationale Criteria: A 12-Month Randomized Clinical Trial. Eur J Dent. 2021 May;15(2):179-192.
23. Shimokawa C, Turbino ML, Giannini M, Braga RR, Price RB. Effect of Curing Light and Exposure Time on the Polymerization of Bulk-Fill Resin-Based Composites in Molar Teeth. Oper Dent 2020;45(3):E141-E55.

24. Amirouche-Korichi A, Mouzali M, Watts DC. Effects of monomer ratios and highly radiopaque fillers on degree of conversion and shrinkage-strain of dental resin composites. Dent Mater 2009;25(11):1411-8.
25. Bin Nooh AN, Nahedh HA, AlRefeai M, Alkhudhairy F. The Effect of Irradiance on the Degree of Conversion and Volumetric Polymerization Shrinkage of Different Bulk-Fill Resin-Based Composites: An In Vitro Study. Eur J Dent. 2021 May;15(2):312-319.
26. Bicalho AA, Pereira RD, Zanatta RF, Franco SD, Tantbirojn D, Versluis A, Soares CJ. Incremental filling technique and composite material--part I: cuspal deformation, bond strength, and physical properties. Oper Dent. 2014 Mar-Apr;39(2):E71-82.
27. Ilie N, Hilton TJ, Heintze SD, et al. Academy of Dental Materials guidance-Resin composites: Part I-Mechanical properties. Dent Mater 2017;33(8):880-94.
of resin based materials. Mater Sci Eng C Mater Biol Appl 2016;63:301-7.
28. Price RB, Rueggeberg FA, Harlow J, Sullivan B. Effect of mold type, diameter, and uncured composite removal method on depth of cure. Clin Oral Investig. 2016 ep;20(7):1699-707
29. Corciolani G, Vichi A, Davidson CL, Ferrari M. The influence of tip geometry and distance on light-curing efficacy. Oper Dent 2008;33(3):325-31.
30. Lima RBW, Troconis CCM, Moreno MBP, Murillo-Gomez F, De Goes MF. Depth of cure of bulk fill resin composites: A systematic review. J Esthet Restor Dent 2018;30(6):492-501.

Tables

Table 1- Specifications of the light-curing (LCU) units tested.

LCU	Manufacturer	Irradiance	Wavelength emission	Tip diameter (mm) [18]	Tip area (cm²)[18]
Radii Xpert	SDI, Bayswater, Victoria, Australia	1575 mW/cm² (Standard)	Monowave	7.8	0.48
Valo	Ultradent, Salt Lake City, Utah, USA	1103 mW/cm² (Standard)	Multipeak	9.5	0.7

Table 2 – Specifications of the tested RBCs.

Composite resin	Manufacturer	Color	Type	Organic Matrix	Filler	Amount of load (wt%/ vol %)	Batch #
Amaris	Voco, Cuxhaven, Germany	TN	Conventional Nanohybrid	Bis-GMA, UDMA, TEGDMA	Inorganics fillers in a methacrylate matrix	80/-	1829623
Filtek One	3M ESPE, St. Paul, MN, USA	A2	Bulk fill	AFM, AUDMA, UDMA and 1,2-dodecano-DMA (DDMA)	Ytterbium trifluoride, non-aggregated silica, non-aggregated zirconia, zirconia/silica clusters	76,5/58	N974887
Aura Bulk Fill	SDI, Bayswater, Victoria, Australia	BKF	Bulk fill	Bis-GMA, UDMA, Bis-EMA, TEGDMA	Silica, signaled barium and glass particles	74,2/65	180143
Tetric Bulk Fill	Ivoclar Vivadent, Schaan, Liechtenstein	IVA	Bulk fill	Bis-GMA, BisEMA and UDMA	Barium aluminum silicate glass, an “Isofiller”, ytterbium fluoride and spherical mixed oxide	75-77/55	94624

Table 3 - Mean degree of conversion values (DC%) and standard deviation (±) for control and experimental groups according to LCU and specimen diameter.

Group	Diameter	LCU	DC%	P-value	LCU	DC%	P-value
Amaris (CG)	*7 mm*	*Valo*	47.2±3.6	-	*Radii Xpert*	45.9±3.4	-
	10 mm		48.6±3.6	-		44.9±3.0	-
Aura Bulk Fill	*7 mm*		51.2±1.9*	=0.004		51.7±3.0*	<0.001
	10 mm		50.4±2.3	=0.344		52.9±2.9*	<0.001
Filtek One	*7 mm*		49.7±2.7	=0.099		47.0±2.0	=0.753
	10 mm		49.6±2.8	=0.741		52.4±2.2*	<0.001
Tetric Bulk Fill	*7 mm*		54.8±1.7*	<0.001		52.1±3.1*	<0.001
	10 mm		53.5±1.5*	<0.001		52.9±2.4*	<0.001

* Indicates significant difference from control group (CG); ANOVA one-way and Dunnett test ($p > 0.05$).

Table 4 - Mean degree of conversion (DC%) and standard deviation (±) for bulk-fill RBCs according to LCU and specimen diameter.

Group	Valo		Radii Xpert	
	7 mm	*10 mm*	*7 mm*	*10 mm*
Aura Bulk Fill	51.2±1.9 Ab€	50.4±2.3 Ab€	51.7±3.0 Aa€	52.9±2.9 Aa€
Filtek One	49.7±2.7 Ab£	49.6±2.8 Ab€	47.0±2.0 Ab£	52.4±2.2 Ab€
Tetric Bulk Fill	54.8±1.7 Aa€	53.5±1.5 Aa€	52.1±3.1 Ba€	52.9±2.4 Ba€

* Capital letters indicate significant differences among LCUs (rows: vertical direction). Lowercase letters indicate significant differences among bulk-fill RBCs (columns: horizontal direction), and symbols indicate significant differences between diameters for the same LCU (rows: vertical direction). Tukey test ($p<0.05$).

Table 5 – Mean Knoop hardness (KHN) values and standard deviation (±) for control and experimental groups according to LCU, specimen diameter and region of analysis.

Group	Diameter	Region	LCU	KHN	P-value	LCU	KHN	P-value
Amaris (CG)	*7 mm*	*Center*	*Valo*	53.0±4.4	-	*Radii Xpert*	51.3±1.0	-
		Periphery		51.8±3.7	-		48.8±0.8	-
	10 mm	*Center*		53.2±1.8	-		54.3±1.7	-
		Periphery		57.6±1.6	-		49.4±1.4	-
Aura Bulk Fill	*7 mm*	*Center*		57.6±2.5*	=0.032		58.8±2.3*	<0.001
		Periphery		55.3±2.2	=0.067		57.0±1.9*	<0.001
	10 mm	*Center*		58.3±2.1*	<0.001		57.5±1.7*	<0.001
		Periphery		57.6±1.6*	<0.001		57.4±3.0*	<0.001
Filtek One	*7 mm*	*Center*		70.5±0.8*	<0.001		69.9±1.7*	<0.001
		Periphery		69.4±1.1*	<0.001		69.7±0.8*	<0.001
	10 mm	*Center*		68.9±2.1*	<0.001		69.0±1.1*	<0.001
		Periphery		68.5±2.0*	<0.001		66.8±1.0*	<0.001
Tetric Bulk Fill	*7 mm*	*Center*		62.1±0.9*	<0.001		59.7±1.7*	<0.001
		Periphery		61.7±0.7*	<0.001		58.6±1.2*	<0.001
	10 mm	*Center*		60.6±1.0*	<0.001		58.1±2.6*	<0.001
		Periphery		60.0±0.8*	<0.001		57.4±1.9*	<0.001

* Indicates significant difference from control group (CG). ANOVA One-way and Dunnett test ($p > 0.05$).

Table 6 – Mean Knoop Hardness (KHN) and standard deviation (±) for bulk-fill RBCs according to LCU, specimen diameter and region of analysis.

Group	Diameter	Valo		Radii Xpert	
		Center	*Periphery*	*Center*	*Periphery*
Amaris	*7 mm*	53.0±4.4 Aa£	51.8±3.7 Ba£	51.3±1.0 Aa£	48.8±0.8 Ba£
	10 mm	53.2±1.8 Aa£	49.6±1.5 Ba£	54.3±1.7 Aa£	49.4±1.4 Ba£
Aura Bulk	*7 mm*	57.6±2.5 Aa£	55.3±2.2 Aa£	58.8±2.3 Aa£	57.0±1.9 Aa£
	10 mm	58.3±2.1 Aa£	57.6±1.6 Aa£	57.5±1.7 Aa£	57.4±3.0 Aa£
Filtek One	*7 mm*	70.5±0.8 Aa£	69.4±1.1 Ba£	69.9±1.7 Aa£	69.7±0.8 Aa£
	10 mm	68.9±2.1 Ab£	68.5±2.0 Bb£	69.0±1.1 Ab£	66.8±1.0 Ab£
Tetric Bulk	*7 mm*	62.1±0.9 Aa£	61.7±0.7 Aa£	59.7±1.7 Aa€	58.6±1.2 Aa€
	10 mm	60.6±1.0 Ab£	60.0±0.8 Ab£	58.1±2.6 Ab€	57.4±1.9 Ab€

* Capital letters indicate significant differences between center and periphery regions (rows: vertical direction). Lowercase letters indicate significant differences between disc diameters (columns: horizontal direction), and symbols indicate significant

differences between LCUs for the same region (rows: vertical direction). Tukey test ($p<0.05$).

Attachments

1. Guide line Journal of European Detistry

Article Types

The following graph shows what types of articles are accepted for publication, and what requirement they may have.

Article Type	Abstract Limit	Keywords Limit	Title Limit	Tables/Figures Limit	References Limit
Original Article (up to **3,500** words)	Up to **350** words (**Structured**: **Objectives, Materials** and **Methods, Statistical analysis, Results, Conclusions**)	**3** to **7** keywords	Up to **35** words	Approximately **5** tables/figures	Up to **40** references
Brief Report (up to **1,800** words)	Up to **250** words (**Structured**: **Objectives, Materials** and **Methods, Statistical analysis, Results, Conclusions**)	**3** to **7** keywords	Up to **35** words	Approximately **5** tables/figures	Up to **20** references
Review Article (up to **4,000** words)	Up to **400** words (**Unstructured** abstract)	**3** to **7** keywords	Up to **35** words	Approximately **5** tables/figures	Up to **75** references
Case Report (up to **2,500** words)	Up to **350** words (**Unstructured** abstract)	**3** to **7** keywords	Up to **35** words	Approximately **7** tables/figures	Up to **25** references
Editorial (up to **1,500** words)	n/a	n/a	n/a	n/a	Up to **15** references
Letter to Editor (up to **300** words)	n/a	n/a	n/a	n/a	Up to **5** references

In Response (up to 300 words)	n/a	n/a	n/a	n/a	Up to **5** references

- **Original Article**: These include randomized controlled trials, intervention studies, studies of screening and diagnostic test, outcome studies, cost effectiveness analyses, case-control series, and surveys with high response rate. The text of original articles amounting to up to **3,500** words (excluding Abstract, References and Tables) should be divided into sections with the headings: Abstract (**Structured format: Objectives, Materials and Methods, Statistical analysis, Results, Conclusions**) up to **350** words, Key-words (**3–7** MeSH words), **Introduction, Materials and Methods, Results, Discussion, Conclusions, References** (up to **40** references), **Tables** and **Figure legends**.

- **Brief Report**: These are similar to original research in that they follow the same format and guidelines, but are designed for small-scale research or research that is in early stages of development. These may include preliminary studies that utilize a simple research design or a small sample size and that have produced limited pilot data and initial findings that indicate need for further investigation. Brief reports are much shorter than manuscripts associated with a more advanced, larger-scale research project. The text of original articles amounting to up to **1,800** words (excluding Abstract, References and Tables) should be divided into sections with the headings: Abstract (**Structured: Objectives, Materials and Methods, Statistical analysis, Results, Conclusions**; up to **200** words), Key-words (**3–7** MeSH words), **Introduction, Materials and Methods, Results, Discussion, Conclusions, References** (up to **20** references), **Tables** and **Figure legends**.

- **Review Article**: It is expected that these articles would be written preferably by individuals who have done substantial work on the subject or are considered experts in the field. The prescribed word count is up to **4,000** words excluding tables, references and abstract. The manuscript may have about **75** references. The manuscript should have an unstructured abstract (up to **400** words) representing an accurate summary of the article. The section titles would depend upon the topic reviewed. Authors submitting review article should include a section describing the methods used for locating, selecting, extracting, and synthesizing data. These methods should also be summarized in the abstract. The journal expects the contributors to give post-publication updates on the subject of review. The update should be brief, covering the advances in the field after the publication of the article and should be sent as a letter to editor, as and when major development occurs in the field.

- **Case Reports/Case Series:** New, interesting and rare cases can be reported. They should be unique, describing a great diagnostic or therapeutic challenge and providing a learning point for the readers. Cases with clinical significance or implications will be given priority. These manuscripts could be of up to **2,500** words (excluding Abstract and references) and manuscript should have an unstructured abstract (up to **350** words), Key-words, Introduction, Case report, Discussion, Conclusion, Reference, Tables and Legends in that order. The case reports could be supported with up to **25** references. The number of images/figures/tables/graphs is to be limited to **7** only.

- **Editorial**: Editorials are solicited by the editorial board or Editor-in-Chief; should be up to **1,500** words and with no more than **15** references.

- **Letter to the Editor (LTE)**: These should be short and decisive observations. They should preferably be related to articles previously published in the Journal or views expressed in the journal. They should not be preliminary observations that need a later paper for validation. The letter could have up to **300** words and **5** references. It could be generally authored by not more than four authors. It should follow the response of authors with similar word count and references with the reading 'In response.'

General Guidelines

- You must submit a digital copy of your manuscript. Hard copy submissions are not accepted.
- Keep the format of your manuscript simple and clear. We will set your manuscript according to our style—do not try to "design" the document.
- The manuscript, including the title page, abstract and keywords, text, references, figure captions, and tables should be typewritten, double-spaced in 12-point font with 1-inch margins all around and saved as one file.
- Each figure should be saved as its own separate file. Do not embed figures within the manuscript file. This requires special handling by Thieme's Production Department.
- Keep abbreviations to a minimum and be sure to explain all of them the first time they are used in the text.
- The manuscripts should be written in American English.
- The authors should use Système International (SI) measurements. For clarity, nonmetric equivalents may be included in parentheses following the SI measurements.
- Use generic names for drugs. You may cite proprietary names in parentheses along with the name and location of the manufacturer.
- Credit suppliers and manufacturers of equipment, drugs, and other brand-name material mentioned in the manuscript within parentheses, giving the company name and primary location.
- Additional material, which is not pivotal, but supporting in nature to the theme of the manuscript, can be submitted as "Supplementary Material" and will be published only online (not in print).

Title Page

- This journal adheres to a **double-blinded peer-review policy**. The title page should **NOT** be included in the main document.
- The title page should list the article title and the corresponding author's full name, degree, title, department, affiliation, mailing address, e-mail address, and telephone and fax numbers. It should also list the full name, degree, title, department, and affiliation of every co-author.

Abstract and Keywords

See the section Article Types for word limits.

The abstract should briefly outline the content of the article and any conclusions it may reach. The keywords should be words a reader would be likely to use in searching for the content of the article.

Main Document

- Please clearly distinguish the hierarchy of headings within the manuscript by using capital letters, underline, italic, and bold styles as necessary.
- As needed, use italic, superscripts, subscripts, and boldface, but otherwise do not use multiple fonts and font sizes.
- Do not insert page or section breaks except where noted in the Author Instructions.
- Use hard returns (the Enter key) only at the end of a paragraph, not at the end of a line. Allow lines of text to break automatically in your word-processing software. Do not justify your text.
- Use only one space, not two, after periods.
- Create tables using the Table function in Microsoft Word.

Acknowledgments

The source of any financial support received and recognition of personal assistance for the work being published should be indicated at the end of the article, just before the Reference section, under the heading Acknowledgments.

Conflict of Interest

All authors (including corresponding and co-authors associated with the manuscript) must make a formal statement at the time of submission indicating any potential conflict of interest that might constitute an embarrassment to any of the authors if it were not to be declared and were to emerge after publication. Such conflicts might include, but are not limited to, shareholding in or receipt of a grant or consultancy fee from a company whose product features in the submitted manuscript or which manufactures a competing product. Should the article be accepted for publication, this information will be published with the paper.

Types of conflicts include: Consulting, Royalties, Research Support, Institutional Support, Ownership, Stock/Options, Speakers Bureau, and Fellowship Support. Any commercial entity whose products are described, reviewed, evaluated, or compared in the manuscript, except for those disclosed in the Acknowledgments section, are potential conflicts.

This journal follows the guidelines of the International Committee of Medical Journal Editors and an ICMJE disclosure of potential conflicts of interest (COI) form must be submitted for each author at the time of manuscript submission. Forms must be submitted even if there is no conflict of interest. It is the responsibility of the corresponding author to ensure that all authors adhere to this policy prior to submission.

A conflict of interest statement must also be included in the manuscript after any "Acknowledgements" and "Funding" sections and should summarize all aspects of any conflicts of interest included on the ICMJE form. If there is no conflict of interest, authors must include 'Conflict of Interest: none declared'.

Please click http://www.icmje.org/conflicts-of-interest to download a Conflict of Interest form. The disclosure information is important in article processing. If the provided forms are incomplete or missing, it can cause delays in publishing of article.

References

References should be the most recent and pertinent literature available. It is essential that they are complete and thoroughly checked. If the reference information is incomplete, good online sites to search for full details are the National Library of Medicine: www.nlm.nih.gov; Books in Print: www.booksinprint.com; PubMed:

www.ncbi.nlm.nih.gov/PubMed/; or individual publisher Web sites.

- References must be listed in AMA style, using Index Medicus journal title abbreviations.

- References follow the article text. Insert a page break between the end of text and the start of references.
- References must be cited sequentially (NOT alphabetically) in the text using superscript numbers.
- By way of exception to AMA style, do not italicize book titles or journal title abbreviations and do not put a period at the end of a reference.
- List all author names, up to and including six names. For more than six authors, list the first three followed by et al.
- References should be styled per the following examples:

1. Citing a journal article:
   Newburger JW, Takahashi M, Burns JC, et al. The treatment of Kawasaki syndrome with intravenous gamma-globulin. N Engl J Med 1986;315:341–347

2. Citing a chapter in a book:
   Toma H. Takayasu's arteritis. In: Novick A, Scoble J, Hamilton G, eds. Renal Vascular Disease. Philadelphia: WB Saunders; 1995:47–62

3. Citing a book:
   Stryer L. Biochemistry. 2nd ed. San Francisco: WH Freeman; 1981:559–596

4. Citing a thesis:
   Stern I. Hemorrhagic Complications of Anticoagulant Therapy [Ph.D. dissertation]. Evanston, IL: Northwestern University; 1994

5. Citing a government publication:
   Food and Drug Administration. Jin Bu Huan Herbal Tablets. Rockville, MD: National Press Office; April 15, 1994. Talk Paper T94-22

6. Citing an online article:
   Rosenthal S, Chen R, Hadler S. The safety of acelluler pertussis vaccine vs whole-cell pertussis vaccine [abstract]. Arch Pediatr Adolesc Med [serial online]. 1996;150:457–460. Available at: http://www.ama-assn.org/sci-pubs/journals/archive/ajdc/vol_150/no_5/abstract/htm. Accessed November 10, 1996

7. Citing a symposium article:
   Eisenberg J. Market forces and physician workforce reform: why they may not work. Paper presented at: Annual Meeting of the Association of American Medical Colleges; October 28, 1995; Washington, DC

Figure Captions

- Figures include photographs or radiographs, drawings, graphs, bar charts, flow charts, and pathways, but NOT lists or tables.
- Figures must be cited sequentially in the text. Number all figures (and corresponding figure captions) sequentially in the order they are cited in the text.
- Figure captions should be written after the reference list. Insert a page break between the end of references and the start of figure captions.
- Figure captions should include a description of the figure and/or each lettered part (A, B, etc.) and of any portions of the figure highlighted by arrows, arrowheads, asterisks, etc.
- For a figure borrowed or adapted from another publication (used with permission), add a credit line in parentheses at the end of each figure legend. This credit line should be a complete bibliographic listing of the source publication (as a reference), or other credit line as supplied by the copyright holder. For example (Reprinted with permission from Calfee DR, Wispelwey B. Brain abscess. Semin Neurol 2000;20:357.)

Tables

- Data given in tables should be commented on but not repeated in the text. Be sure that lists or columns of related data are composed in a word-processing program like the rest of the text.
- Do not intersperse tables in the text. Tables should appear after the figure captions. Insert a page break between the end of the figure captions and the start of the tables.
- Tables must be double-spaced and numbered in the same sequence they are cited in the text. A short descriptive title should be provided for each table.
- If a table contains artwork, supply the artwork separately as a digital file.
- For tables borrowed or adapted from another publication (used with permission), add a credit line as the first footnote beneath each table. This credit line should be a complete bibliographical listing of the source publication (as a reference), or other credit line as supplied by the copyright holder. For example, "Reprinted with permission from Calfee DR, Wispelwey B. Brain abscess. Semin Neurol 2000;20:357."
  ("Data from . . ." or "Adapted from . . ." may also be used, as appropriate.)
- Other footnotes for tables should be indicated in the table using superscript letters in alphabetical order.
- Any abbreviations used in the table should be explained at the end of the table in a footnote.

DIGITAL ARTWORK PREPARATION

General Guidelines

- It is best to use Adobe Photoshop to create and save images, and Adobe Illustrator for line art and labels.
- Do not submit art created in Microsoft Excel, Word, or PowerPoint. These files cannot be used by the typesetter.
- Save each figure in a separate file.
- Do not compress files.
- All black-and-white and color artwork should be at a resolution of 300 dpi (dots per inch) in TIFF format. Line art should be 1,200 dpi in EPS or TIFF format. Contact the Production Editor at Thieme if you are unsure of the final size.
- It is preferable for figures to be cropped to their final size (approximately 3½ inches for a single column and up to 7 inches for a double column), or larger, and in the correct orientation. If art is submitted smaller and then has to be enlarged, its resolution (dpi) and clarity will decrease.

  Note: Lower resolutions (less than 300 dpi) and JPEG format (.jpg extension) for grayscale and color artwork are strongly discouraged due to the poor quality they yield in printing, which requires 300 dpi resolution for sharp, clear, detailed images. JPEG format, by definition, is a lower resolution (compressed) format designed for quick upload on computer screens.

Black-and-White Art

- Black-and-white artwork can be halftone (or grayscale) photographs, radiographs, drawings, line art, graphs, and flowcharts. Thieme will only accept digital artwork.
- If possible, do not send color art for conversion to black-and-white. Do the conversion yourself so that you can check the results and confirm in advance that no critical details are lost or obscured by the change to black-and-white.
- For best results, line art should be black on a white background. Lines and type should be clean and evenly dark. Avoid screens or cross-hatching, as they can darken or be uneven in printing and lead to unacceptable printing quality.

Color Art

- All color artwork should be saved in CMYK, not RGB.

Art Labels

- Arrows, asterisks, and arrowheads (or other markers) should be white in dark or black areas and black in light or white areas, and large in size. If not, these highlighting marks may become difficult to see when figures are reduced in size during the typesetting process.
- Use 1-point (or thicker) rules and leader lines.

- Capitalize the first word of each label and all proper nouns. Consider using all capitals if you need a higher level of labels.
- Where there are alternate terms or spellings for a named structure, use the most common one and make sure it is consistent with what is used in the text.
- Avoid using multiple fonts and font sizes for the labels; use only one or two sizes of a serif font.