Pesquisa Brasileira em Odontopediatria e Clínica Integrada 2022; 22:e210110
https://doi.org/10.1590/pboci.2022.041
ISSN 1519-0501 / eISSN 1983-4632

ORIGINAL ARTICLE

Effect of Light-Curing Unit Type and Bulk-Fill Composite Resins with Different Photoinitiators on Marginal Gaps of Class II Restorations

Fereshteh Naser Alavi[1], Farideh Darabi[2], Ashkan Salari[3], Arefeh Dehghan[4]

[1]Dental Sciences Research Center, Department of Operative Dentistry, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran.
[2]Department of Operative Dentistry, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran.
[3]Dental Sciences Research Center, Department of Periodontics, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran.
[4]School of Dentistry, International branch of Guilan University of Medical Science, Anzali, Iran.

Correspondence: Fereshteh Naser Alavi, Guilan University of Medical Science, School of Dentistry, Lacan Road, Gas Square, Rasht, Iran. **E-mail:** minanasseralavi@yahoo.com

Academic Editor: Myroslav Goncharuk-Khomyn

Received: 28 May 2021 / **Review:** 24 September 2021 / **Accepted:** 22 January 2022

How to cite: Alavi FN, Darabi F, Salari A, Dehghan A. Effect of light-curing unit type and bulk-fill composite resins with different photoinitiators on marginal gaps of Class II restorations. Pesqui Bras Odontopediatria Clín Integr. 2022; 22:e210110. https://doi.org/10.1590/pboci.2022.041

ABSTRACT
Objective: To evaluate the effect of two types of light-curing units (second and third generations) and two types of bulk-fill composite resins with different photoinitiators - Tetric N-Ceram Bulk Fill (TNCB) and X-tra Fil (XTF) on gap formation at the gingival margins of Cl II restorations. **Material and Methods:** Fifty-six standard Cl II cavities were prepared on the mesial and distal surfaces of premolar teeth, with the gingival margin of the cavities 1 mm apical to the CEJ. The samples were randomly assigned to two groups based on the composite resin type and two subgroups based on the light-curing unit type and restored. After 5000 rounds of thermocycling, gingival margin gap in each sample was measured in µm under an electron microscope at ×2000 magnification. Data were analyzed by two-way ANOVA and Tukey tests (α=0.05). **Results:** Marginal gaps of TNCB composite resin were significantly smaller than those of XTF composite resin ($p<0.001$). There were no significant differences between the two light-curing units in each group ($p=0.887$ with XTF and $p=0.999$ with TNCB). **Conclusion:** The gaps at gingival margins of Cl II cavities with TNCB bulk-fill composite were smaller than XTF composite resin. Both composite resins can be cured with both the second- and third-generation LEDs.

Keywords: Composite Resins; Curing Lights, Dental; Dental Marginal Adaptation.

Introduction

Currently, composite resins are the most common restorative materials for anterior and posterior teeth. One of the concerns related to light-cured composite resins is the limited light penetration that might lead to inadequate curing depth and polymerization, which is more common in the posterior teeth [1]. In addition, polymerization shrinkage in composite resin materials causes stress at the tooth-restoration interface, resulting in gap formation, microleakage, and recurrent caries, especially at dentinal margins [2].

One technique to decrease the adverse effects of polymerization shrinkage and achieve optimal curing is the incremental placement (at 2-mm thickness) of conventional composite resins. However, this technique is clinically complicated and time-consuming and increases the odds of bubble entrapment between the layers and cavity contamination [3].

In an attempt to solve this problem, bulk-fill composite resins were produced and marketed. It is claimed that bulk-fill composite resins can be applied at 4–5-mm thickness with proper curing depth, polymerization and low polymerization shrinkage [1]. Previous studies have shown that the adequate curing depth of bulk-fill composite resins and marginal adaptation are comparable to conventional composite resins [1,4]. Different mechanisms have been used in bulk-fill composite resins to increase the curing depth and monomer conversion rate. In some composite resins, increased translucency has been used to increase the penetration of the curing light. However, some others have used new alternative photoinitiators [5].

The most commonly used photoinitiator in composite resins is camphorquinone, with the optimal light absorption at 470 nm. However, one of the new alternative photoinitiators is Ivocerin, introduced by Ivoclar Vivadent, to provide more absorption spectrum in the low wavelengths (390–445 nm with a peak absorption at 408 nm). Based on the manufacturer's claims, using Ivocerin as a photoinitiator, with a higher absorption ability, along with camphorquinone, in bulk-fill composite resins can lead to an optimal curing depth in 4-mm layers [6].

Adequate polymerization is critical for achieving satisfactory clinical efficacy in composite resin restorations and preventing monomer solubility [7]. Activating different photoinitiators requires a light-curing unit with a suitable wavelength to match their absorption spectrum [8]. Second-generation LED (light-emitting-diode) units are the most popular among dentists. The peak of incident photons of these LEDs (monowave) is in the maximum absorption of camphorquinone, providing favorable curing for composite resins containing camphorquinone photoinitiators [9].

After producing new photoinitiators, third-generation (polywave) LED light-curing units were manufactured that emitted ultraviolet light in addition to blue light. After incorporating ultraviolet light, the photons released from this generation of LEDs exhibited the ability to activate any photoinitiator until now [9]. Although polywave and monowave LEDs can produce a similar radiation dose, differences in their emitted photons might significantly affect the activation of photoinitiator systems and the final polymerization of composite resins. In fact, the narrow wavelength of these monowave LEDs might limit their ability to cure bulk-fill composite resins containing different photoinitiators with diverse absorption peaks [10].

Some studies have shown that light-curing unit type might affect the degree of conversion of composite resins and the residual monomers [11]. For example, Sahadi et al. [12] reported that third-generation LED increased the microhardness of Tetric-Evoceram composite resin compared to second-generation LED.

Considering differences in the composition of bulk-fill composite reins [13], it is necessary to be aware of the efficacy of different materials and suitable light-curing units to improve these materials' polymerization efficacy, bonding quality, and marginal integrity after aging. Also, these factors are critical in gap formation and failure of restoration in clinical positions. Since adequate studies are not available on the effect of the third-generation LEDs (polywave) concerning marginal gap formation in bulk-fill composite resins containing new photoinitiators, the present study aimed to evaluate the effects of different types of LEDs (second and third generations) and bulk-fill composite resins with different photoinitiators (Tetric N-Ceram Bulk Fill (TNCB) [with Ivocerin photoinitiator] and X-tra Fil (XTF) on the formation of gaps in gingival margins of Cl II cavities using a scanning electron microscope (SEM) after *in vitro* aging. The null hypotheses were: (1) there would be no significant difference between tested composite resins, and (2) no significant difference among the effect of light curing units.

Material and Methods

Ethical Clearance

The study protocol was approved by the Ethics Committee of Gulian University of Medical Sciences (IR.GUMS.REC.1399.288).

Study Design and Sample

The present *in vitro* study was carried out on 28 human premolar teeth extracted for orthodontic treatment. All the teeth were sound with no caries, cracks, fractures, or anomalies. The debris and soft tissues were removed with a scaler, and the teeth were cleaned with a slurry of pumice and a rubber cup. Then teeth were stored in 0.1% thymol solution in a refrigerator (4 °C) for 24 h.

Cavity Preparation

Standard Cl II cavities were prepared on the mesial and distal surfaces of teeth, measuring 4 mm in buccolingually width and 1.5 mm in mesiodistally depth, with butt joint margins. The gingival margin was placed 1 mm apical to the CEJ. A sharp coarse-grained diamond fissure bur (Stoddard, England) was used to prepare the cavities under air and water cooling. The cavity dimensions were measured with a graduated probe and confirmed. The prepared teeth were randomly assigned to two groups in terms of the composite resin type and into two subgroups in terms of the type of the light-curing unit for restoration (n=14 cavities) (Group 1 - A: X-tra Fil composite resin + second-generation LED and B: X-tra Fil composite resin + third-generation LED; Group 2 - A: Tetric N-Ceram Bulk Fill composite resin + second-generation LED and B: Tetric N-Ceram Bulk Fill composite resin + third-generation LED). In each tooth, the mesial and distal cavities were used for the same subgroup. Tables 1 and 2 present the characteristics of composite resins and light-curing units used in the present study.

Table 1. The characteristics of composite resin materials used in the study.

Composite Resin	Composition	Classification
X-tra Fil [XTF], VOCO, Cuxhaven, Germany. Shade: universal Lot: 1903271	Bis-GMA, UDMA, TEGDMA, barium-boron-aluminosilicate glass	Hybrid (packable) Fillers: 86% wt, 70% vol
Tetric N-Ceram Bulk Fill [TNCB], Ivoclar, vivadent, Schann, Liechtenstein. Shade: IVB Lot: W94084	Bis-GMA, Bis-EMA, UDMA, Polymer Filler (17.0%) (Barium glass filler, Ytterbium trifluoride), Mixed oxide	Hybrid (packable) Fillers: 75-77 wt%, 53-55 vol%

Bis-GMA: Bisphenol A Glycol Dimethacrylate; UDMA: Urethane Dimethacrylate; TEGDMA: Triethylene Glycol Dimethacrylate; Bis-EMA: Bisphenol Aethoxylated Dimethacrylate.

Table 2. The characteristics of light-curing units used in the study.

Light-Curing Unit Type	Spectral Range (nm)	Irradiance (mW/cm²)
LED.F (Woodpecker, China); second-generation LED	420-480	1200 (normal mode)
X-CURE (Woodpecker, China); third-generation LED	385-515	1200 (soft mode)

The Tofflemire matrix band was placed around the tooth to restore the cavities, and the thickness of each composite resin layer was marked with a water-resistant marker. G-Premio Bond adhesive (GC Corporation, Tokyo, Japan, Lot: 1905282) was used in all the cavities according to the manufacturer's instructions. The self-etch bonding protocol was applied on all surfaces and dried after 10 seconds with the maximum pressure of the air drying syringe for 5 seconds. Then, light-curing was carried out for 10 seconds in subgroups A (LED.F) and 15 seconds in subgroup B (X-cure). The first layer of the composite resin was placed 4 mm in thickness. Then the subsequent layer was placed until the cavity was fully restored. Each layer was light-cured according to the manufacturer's instructions based on the light-curing protocol: for 10 seconds in subgroups A (LED.F) and 15 seconds in subgroup B (X-cure) at a right angle to and barely touching the occlusal margin. Because of using the same irradiance of mentioned light curing units, we used soft mode of X-cure and normal mode of LED.F. According to the manufacturer's instructions, during the soft mode usage, 5 seconds more time was used for curing the restorative materials. The light intensity of the light-curing units was repeatedly checked by a radiometer (DTE-LM-1, Woodpecker, China) during the procedure.

The restorations were polished by polishing disks (Soflex, 3M Dental Products, St Paul, MN, USA) from coarse to medium to fine according to the manufacturer's instructions, followed by incubation in distilled water at 37 °C for 24 hours. Finally, a 5000-round thermocycling (Dorsa apparatus, Tehran, Iran) procedure was carried out at 5/55°C with a dwell time of 30 seconds and a transfer time of 10 seconds in a water bath.

The teeth were divided in the mesiodistal direction into buccal and lingual halves with a diamond disk (Diamant Gmbh, D & Z, Berlin, Germany). The samples were mounted on aluminum stubs and placed within the SEM (Mira/LMU, Tescan, Czech Republic) after drying, preparing, and gold-sputtering. A magnification of ×2000 was used to measure gaps at dentin gingival margins. The SEM software was used to measure the marginal gap width by determining two points on each side of the gap (one on the tooth side and one on the restoration side and measuring the distance between these two points in µm. The width of the marginal gap was measured at three points (external, middle and internal) and their means were determined as the marginal gap in each sample (Figure 1).

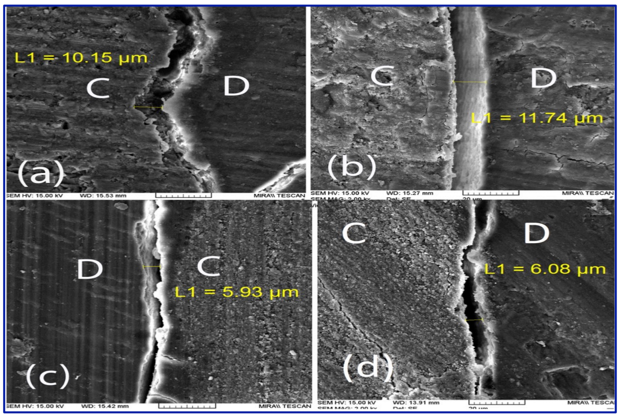

Figure 1. Evaluation of gap formation under a scanning electron microscope at ×2000: a (XTF, second-generation LED), b (XTF, third-generation LED), c (TNCB, second-generation LED) and d (TNCB, third-generation LED) at dentin-composite interface. C: composite resin; D: dentin.

Data Analysis

Two-way ANOVA was used to analyze the effect of materials and light-curing units. Post hoc Tukey tests were used for two-by-two comparisons. Statistical analyses were carried out with SPSS 26 (IBM SPSS Statistics, Armonk, NY, USA) at a significance level of $p<0.05$.

Results

Table 3 presents the means and standard deviations of the widths of restoration marginal gaps at the dentin–composite resin in study groups. Shapiro-Wilk test was used to evaluate the normal distribution of data. In addition, variance homogeneity of the study groups was analyzed with Leven's test.

Two-way ANOVA showed only the significant effect of composite resin type on marginal gaps ($p<0.001$, $F=36.55$). However, the effect of the light-curing unit and the cumulative effect of these two variables were not significant ($p=0.627$, $F=0.23$ and $p=0.596$, $F=0.28$, respectively).

Post hoc Tukey tests showed that the marginal gaps in the XTF composite resin between the second- and third-generation LEDs were significantly higher than that with TNCB composite resin between the second- and third-generation light-curing units ($p<0.001$). However, the means of marginal gaps were not significantly different between the second- and third-generation LEDs in XTF and TNCB composite resins ($p=0.887$ and $p=0.999$, respectively).

Table 3. The means of gingival marginal gap measurements in study groups in µm.

Composite Resin Type	Light Cure Unit Type	
	Second-generation LED Mean (SD)	Third-generation LED Mean (SD)
X-tra Fil	10.99 (4.75)^{A}	10.08 (3.34)^{A}
Tetric-N-Ceram Bulk Fill	5.16 (2.44)^{B}	5.20 (2.04)^{B}

The differences between dissimilar letters are significant ($p<0.05$).

Discussion

The present study evaluated the effect of two bulk-fill composite resins, one with Ivocerin photoinitiator (TNCB) and one without this photoinitiator (XTF) and two types of LED light-curing units with different radiation wavelengths, second- and third-generation on gap formation at the dentin gingival margins of Cl II restorations. Based on the results, the marginal gaps in cavities restored with the TNCB composite resin were significantly less than in cavities restored with the XTF composite resin.

The degree of conversion and curing depth of composite resin materials might affect the quality of the bond at the restoration interface. Improper curing results in inadequate bond strengths of composite resin to the tooth structure, causing gap formation at the tooth–restoration interface [14]. Different factors might affect the degree of conversion and curing of composite resin, including the light source and its energy density, the wavelength of the light-curing unit, the duration of irradiation, the chemical formula of the organic matrix of composite resin, the type and amount of the photoinitiator, and the distribution and percentage of inorganic fillers [15,16]. Besides, the composite resin disintegrates in the oral cavity under the effect of different events, including thermal cycles in the deep parts of the gingival margins of Cl II cavities. Previous studies have shown an increase in the width of dentinal marginal gaps after artificial aging [17,18].

TNCB composite resin has a germanium-based photoinitiator (Ivocerin) in its structure and has a curing activity higher than camphorquinone. In addition, Ivocerin begins its polymerization activity by producing two free radicals, with no need for adding amine; such activity is more effective than the initiation activity of the camphorquinone system in which one free radical is produced [13,19]. Consistent with this finding, Jung and Park [20] reported higher depth-to-surface hardness in TNCB composite resin due to the Ivocerin photoinitiator and better polymerization depth.

The gap formation is a complex issue, and it is not possible to be satisfied with the difference of photoinitiators alone. In this context, structural differences in materials are also important and influential. According to the manufacturer, the use of Aessencio technology in the TNCB composite resin is new progress, based on which the refractive index of resin monomers matches that of filler particles, which leads to a very translucent structure in the material, facilitating easy penetration of light without any barriers to the curing light. This helps achieve a proper curing depth in thicker layers. Besides, the penetration depth of the curing light in the material depth depends on the filler content in the composite resin structure [21]. Evaluation of the volume of the fillers in the composite resins used in the present study showed a lower filler content in TNCB (53–55%) compared to XTF (70%).

Another consideration about gap formation is Polymerization shrinkage stresses that are affected by the polymerization speed, the magnitude of polymerization shrinkage, composition, filler content and high elastic modulus of composite resin [22,23]. Marginal gaps form when the stresses are greater than the material's bond strength. In addition, the elastic modulus is different between bulk-fill composite resins, with a significant relationship between the filler content and the elastic modulus of the material [24]. In this context, Ilie et al. [13] showed that XTF composite resin with a higher filler content exhibited a higher elastic modulus than other bulk-fill composite resins.

Polymerization speed of the composite resin affects polymerization stress, too. For example, a lower curing speed in TNCB composite resin with reaction modulation formulation provides a longer time to overcome shrinkage forces before complete setting [23].

Polymerization shrinkage volume is another factor involved in interfacial stresses. According to the manufacturer, the volumetric shrinkage in TNCB is 1.94%, slightly higher than that of XTF (1.81%). However, this is not the only factor in this respect [22]. It is possible that a composite resin, despite having higher polymerization shrinkage, allows the restoration margins to decrease shrinkage stresses at the tooth–restoration interface because of lower elastic modulus and shrinkage speed [13].

Therefore, in the present study, attention to these characteristics in TNCB in association with the catalyst initiating system and the modified monomer type, modulation formulation of the reaction with stress-releasing monomers, silanized fillers, and different fillers, such as polymer particles, can all help explain the higher success rate of this composite resin and its lower marginal gap formation compared to the XTF composite resin. Van Ende et al. [25] reported that the type of bulk-fill composite resin significantly affected its bond quality to the tooth structure, and different bulk-fill composite resins created different stresses and bond strengths at the bonding interface. In contrast to the present study, Hoseinifar et al. [26] reported no difference in the microleakage of XTF and TCNB composited resins in Cl II cavities restored with the etch and rinse adhesive system after 2000 rounds of thermocycling and evaluation under a stereomicroscope. The discrepancy in the results of these two studies might be attributed to differences in study designs, adhesive systems, and the method used to evaluate the bonding interface. In this study, the marginal gap measurement was done using SEM to evaluate the efficacy of the restorative materials after aging. In studies, the use of SEM is an accurate method for assessing the prediction of clinical performance of materials [4,17].

Another finding of the present study showed the similar effect of the two types of light-curing units on dentin marginal gaps in both types of composite resin tested. Despite the presence of Ivocerin photoinitiator with 408-nm absorption peak [6] in the TNCB composite resin, no significant difference was observed in second- and third- generation LEDs in exciting this photoinitiator and its final performance on marginal gap formation. Consistent with the present study, Menees et al. [27] reported no significant differences between the monowave and polywave LED light-curing units in the evaluation of the curing depth of bulk-fill composite resins containing Ivocerin (TNCB) and without it (Filtek bulk-fill).

Although Ivocerin has peak absorption at 408 nm, approximately 50% of its light absorption occurs at 440 nm [6]. In the present study, the second-generation LED (LED.F) had a radiation wavelength spectrum of 420–480 nm. Therefore, such an overlap in the absorption spectrum of Ivocerin with the LED.F radiation spectrum might have made it possible to activate Ivocerin in the TNCB composite resin. On the other hand, a study showed that most violet light (short wavelength) irradiated by polywave LED is absorbed in the superficial layers of composite resins. Besides, new photoinitiators with an absorption capacity of several folds that of camphorquinone absorb most photons of short wavelengths on the surface layers and do not allow them to penetrate the deep layers [28].

Moreover, the filler particles mostly tend to scatter short wavelengths of light; therefore, most of the violet spectrum is scattered in the upper layers, and most of the light exposure in deep layers of composite resin belongs to the blue spectrum [28]. Therefore, in the present study, attention to these might explain the similarity of the function of these two LED types at the bonded interface in the gingival area. Concerning the XTF composite resin, the penetration of blue light and its radiation exposure in the polywave unit might have been sufficient at the gingival interface, leading to marginal sealing similar to that with the monowave light-curing unit.

On the other hand, in a study by Price et al. [29], the hardness of composite resins cured with a monowave light-curing unit was approximately 80% of composite resins cured with polywave light-curing units; besides, monowave light-curing units could not cure some composite resins compared to polywave light-curing units. Such differences might be attributed to diversities in composite resin materials, including the difference in the photoinitiators (Lucerin TPO) with sensitivity to lower wavelengths (<420 nm) in that study compared to the present study (Ivocerin). It has been reported that the most important difference between studies is in the type of composite resin materials used because polymerization shrinkage and the material's performance depend on the composite resin's type and composition [30].

The present *in vitro* study was carried out on extracted teeth so that it was possible to completely adapt the light-curing unit's tip on restorations. The restorations underwent a 5000-round thermocycling procedure to simulate the moist condition and the thermal cycles of the oral cavity, which is a moderate time interval. In the oral cavity pulpal fluids, pH changes and occlusal forces also may affect the results. Therefore, it is suggested that future studies be carried out under conditions more similar to the clinical conditions for longer periods with more diverse materials.

Conclusion

The marginal gaps at the gingival margin areas of Cl II restorations in the TNCB composite resin with Ivocerin photoinitiator were less than those with the XTF composite resin. In addition, both the second-generation and third-generation LED light-curing units exhibited a similar effect on the formation of marginal gaps in both types of composite resin. Thus both LEDs can be used to curing these composite resins in restorative procedures.

Authors' Contributions

FNA	https://orcid.org/0000-0002-4879-5434	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing.
FD	https://orcid.org/0000-0003-1706-2243	Conceptualization, Investigation, Data Curation and Writing - Review and Editing.
AS	https://orcid.org/0000-0003-4504-5141	Data Curation and Writing - Review and Editing.
AD	https://orcid.org/0000-0001-6967-137X	Conceptualization, Methodology, Formal Analysis and Writing - Review and Editing.
All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.		

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

References

[1] Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin-composites. Dent Mater 2014; 30(2):149-54. https://doi.org/10.1016/j.dental.2013.10.011

[2] Behery H, El-Mowafy O, El-Badrawy W, Saleh B, Nabih S. Cuspal deflection of premolars restored with bulk-fill composite resins. J Esthet Restor Dent 2016; 28(2):122-30. https://doi.org/10.1111/jerd.12188

[3] Ferracane JL. Resin composite - state of the art. Dent Mater 2011; 27(1):29-38. https://doi.org/10.1016/j.dental.2010.10.020

[4] Darabi F, Tayefeh-Davalloo R, Tavangar SM, Naser-Alavi F, Boorboo-Shirazi M. The effect of composite resin preheating on marginal adaptation of class II restorations. J Clin Exp Dent 2020; 12(7):682-7. https://doi.org/10.4317/jced.56625

[5] Arikawa H, Shinohara N, Takahashi H, Kanie T, Fujii K, Ban S. Light transmittance characteristics and refractive indices of light-activated pit and fissure sealants. Dent Mater 2010; 29(1):89-96. https://doi.org/10.4012/dmj.2009-042

[6] Moszner N, Fischer UK, Ganster B, Liska R, Rheinberger V. Benzoyl germanium derivatives as novel visible light photoinitiators for dental materials. Dent Mater 2008; 24(7):901-7. https://doi.org/10.1016/j.dental.2007.11.004

[7] Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. J Dent 2014; 42(8):993-1000. https://doi.org/10.1016/j.jdent.2014.05.009

[8] Rueggeberg FA, Blalock JS, Callan RS. LED curing lights--what's new? Compend Contin Educ Dent 2005; 26(8):586,588,590-1.

[9] Rueggeberg FA. State-of-the-art: dental photocuring - a review. Dent Mater 2011; 27(1):39-52. https://doi.org/10.1016/j.dental.2010.10.021

[10] Price RB, Felix CA. Effect of delivering light in specific narrow bandwidths from 394 to 515nm on the micro-hardness of resin composites. Dent Mater 2009; 25(7):899-908. https://doi.org/10.1016/j.dental.2009.01.098

[11] Moreira Fdo C, Antoniosi Filho NR, Souza JB, Lopes LG. Sorption, solubility and residual monomers of a dental adhesive cured by different light-curing units. Braz Dent J 2010; 21(5):432-8. https://doi.org/10.1590/s0103-64402010000500010

[12] Sahadi BO, Price RB, André CB, Sebold M, Bermejo GN, Palma-Dibb RG, 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. https://doi.org/10.1590/1807-3107bor-2018.vol32.0122

[13] Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Oper Dent 2013; 38(6):618-25. https://doi.org/10.2341/12-395-L

[14] Taylor MJ, Lynch E. Microleakage. J Dent 1992; 20(1):3-10. https://doi.org/10.1016/0300-5712(92)90002-t

[15] Choudhary S, Suprabha B. Effectiveness of light emitting diode and halogen light curing units for curing microhybrid and nanocomposites. J Conserv Dent 2013; 16(3):233-7. https://doi.org/10.4103/0972-0707.111322

[16] Mohammadi N, Alavi FN, Rikhtehgaran S, Chaharom MEE, Salari A, Kimyai S, et al. Effect of bleaching method and curing time on the surface microhardness of microhybrid composite resin. Maedica 2020; 15(3):359-64. https://doi.org/10.26574/maedica.2020.15.3.359

[17] Peutzfeldt A, Mühlebach S, Lussi A, Flury S. Marginal gap formation in approximal "bulk fill" resin composite restorations after artificial ageing. Oper Dent 2018; 43(2):180-9. https://doi.org/10.2341/17-068-L

[18] Carreira M, Antunes PV, Ramalho A, Paula A, Carrilho E. Thermocycling effect on mechanical and tribological characterization of two indirect dental restorative materials. J Braz Soc Mech Sci Eng 2017; 39(1):1–17. https://doi.org/10.1007/s40430-016-0579-6
[19] Jang JH, Park SH, Hwang IN. Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flowable resin. Oper Dent 2015; 40(2):172-80. https://doi.org/10.2341/13-307-L
[20] Jung JH, Park SH. Comparison of polymerization shrinkage, physical properties, and marginal adaptation of flowable and restorative bulk fill resin-based composites. Oper Dent 2017; 42(4):375-86. https://doi.org/10.2341/16-254-L
[21] Krämer N, Lohbauer U, García-Godoy F, Frankenberger R. Light curing of resin-based composites in the LED era. Am J Dent 2008; 21(3):135-42.
[22] Davidson CL, Feilzer AJ. Polymerization shrinkage and polymerization shrinkage stress in polymer-based restoratives. J Dent 1997; 25(6):435-40. https://doi.org/10.1016/s0300-5712(96)00063-2
[23] Braga RR, Ballester RY, Ferracane JL. Factors involved in the development of polymerization shrinkage stress in resin-composites: a systematic review. Dent Mater 2005; 21(10):962-70. https://doi.org/10.1016/j.dental.2005.04.018
[24] Ilie N, Rencz A, Hickel R. Investigations towards nano-hybrid resin-based composites. Clin Oral Investig 2013; 17(1):185-93. https://doi.org/10.1007/s00784-012-0689-1
[25] Van Ende A, De Munck J, Van Landuyt K, Van Meerbeek B. Effect of bulk-filling on the bonding efficacy in occlusal class i cavities. J Adhes Dent 2016; 18(2):119-24. https://doi.org/10.3290/j.jad.a35905
[26] Hoseinifar R, Mofidi M, Malekhosseini N. The effect of occlusal loading on gingival microleakage of bulk fill composites compared with a conventional composite. J Dent 2020; 21(2):87-94. https://doi.org/10.30476/DENTJODS.2019.77861.0
[27] 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.
[28] Albuquerque PP, Bertolo ML, Cavalcante LM, Pfeifer C, Schneider LF. Degree of conversion, depth of cure, and color stability of experimental dental composite formulated with camphorquinone and phenanthrenequinone photoinitiators. J Esthet Restor Dent 2015; 27(Suppl 1):S49-57. https://doi.org/10.1111/jerd.12131
[29] Price RB, Fahey J, Felix CM. Knoop hardness of five composites cured with single-peak and polywave LED curing lights. Quintessence Int 2010; 41(10):e181-91.
[30] Lee SK, Kim TW, Son SA, Park JK, Kim JH, Kim HI, et al. Influence of light-curing units on the polymerization of low-shrinkage composite resins. Dent Mater J 2013; 32(5):688-94. https://doi.org/10.4012/dmj.2013-027