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Microleakage Evaluation of Photopolymerization Efficiency in Different Layering Methods of New Generation Led Light Devices

SUMMARY

Background/Aim: *The aim of this study was to examine the microleakage values after restoring the prepared Class II box cavities using two different composite resins with three different layering methods and polymerizing them with five different LED light devices.* ***Material and Methods:*** *Class II box cavities were prepared in 150 extracted mandibular molars. Nanoceramic composite resin (Ceram.x SphereTEC one universal A2, Dentsply, Germany) and bulk fill composite resin (SDR flow+ A2, Dentsply, Germany) were used for the restoration of the cavities. Teeth were restored with three different layering methods (bulk fill, horizontal layering, and centripetal buildup technique) and five different LED light devices [(Smartlite Focus, Dentsply, USA), (Led.E, Woodpecker, China), (Valo Cordless, Ultradent, USA), (Bluephase N, Ivoclar Vivadent, Liechtenstein), (D-Light Pro (GC, USA)] and then subjected to microleakage analysis. Kruskal Wallis and Mann Whitney U test were used for statistical analysis. The data was evaluated under $p<0.005$ significant level.* ***Results:*** *Using different layering methods did not affect microleakage scores statistically ($p=0.7683$). Applying bulk-fill composite resin with 2 mm horizontal layers or using the centripetal buildup technique did not show significant differences in microleakage. Second- and third-generation light devices demonstrated no statistical difference in microleakage ($p=0.9075$).* ***Conclusions:*** *Using different layering methods and different curing units did not make any difference in microleakage.*

Keywords: Composite Resins; Curing Lights, Dental; Dental Leakage; Dental Restorations, Permanent.

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Introduction

Composite resins have been successfully and widely used in dentistry for many years to replace amalgam for the teeth restoration[1]. Composite resins are expected to have mechanical properties similar to enamel and dentin and to be long-lasting[2]. Despite the improvements in resin-based composite resins, insufficient polymerization depth is one of the most significant disadvantages[3]. In recent years, bulk-fill composites have provided advantages in terms of time and cost[4]. The advantage of bulk fill composite is that it can be placed in the cavity up to 4 mm, instead of the layering technique, without any adverse effects on polymerization shrinkage, adaptation to the cavity, and the degree of conversion[5].

LED (Light Emitting Diode) light devices are the most used light source for light-cured materials today due to their efficiency and cost[6]. First-generation LED light devices have limited light intensity. The second-generation LED light devices, released later, reached higher light intensity. However, the wavelength of both is limited to 420-490 nm. Finally, 3rd generation LED light devices, which have the ability to polymerize all photoinitiators, have been introduced[7]. Due to the yellowish color of camphoroquinone, the most widely used photoinitiator in composite resins, composite resins containing alternative photoinitiators have been introduced in recent years. Since these alternative photoinitiators are closer to the wavelength of violet light (410 nm and below) and second-generation light devices cannot provide light at 420 nm and below, an effective polymerization could not be achieved. An additional color emitter has been added to the LED pad to solve the narrow wavelength problem of blue LED (single-peak) light devices. Due to these different LED color emitters, the wavelength of the device has expanded to 380-500 nm. The light devices that can provide this blue and purple light together are called "third-generation LED light devices (polywave)"[8].

Polymerization shrinkage is one of the biggest problems of composite resins[9]. During the polymerization of the composite, approximately 1-5% volume change occurs[10]. Microleakage is the inevitable result of polymerization shrinkage in composite resins, and some studies have reported a correlation between shrinkage stresses and microleakage[11,12]. Microleakage is a condition characterized by the penetration of acids, enzymes, ions, bacteria, and bacterial products from the margins of the restorations, causing postoperative sensitivity, recurrent caries, pulp inflammation, and even necrosis. The difference in the thermal expansion coefficient between the composite material and the tooth tissue, the polymerization shrinkage, the wear of the composite resin over time, the elastic deformation, the carelessness of the clinician, and the non-compliance with the application rules might be causes of microleakage[13]. Microleakage reduces when the restorative materials bonded successfully with the tooth. However, no restorative material can completely close the margins and prevent microleakage in long term[14].

The hypothesis of this study is; "Third-generation LED light devices show better polymerization efficiency than second-generation LED light devices" and "The application method of the composite in Class II box cavities is effective on microleakage".

The aim of this study was to determine the polymerization efficiency of light devices and to assess the microleakage scores after the restoration of Class II box cavities using LED light devices with different layering methods.

Material and Methods

Preparation of samples

The study was performed in conformance with the Declaration of Helsinki ethical guidelines. The ethical approval was received on 28.06.2018 with the protocol number 2018-218. In the study; 150 lower molars, which were extracted in the last six months due to periodontal and surgical reasons, without caries, without restoration, without hypoplasia and cracks, were used. Periodontal tissue and debris on the teeth were removed with a periodontal scaler. The teeth were kept in distilled water until the study began. Then, an artificial premolar tooth was embedded in acryl (SC, İmcryl, Turkey) adjacent to each tooth mesial.

Standard Class II box cavities were prepared on the mesial surface of all teeth with diamond burs (Adia, Turkey) by the same investigator under air and water cooling. The bur was renewed after the preparation of every 5 teeth. Each cavity was prepared with a buccolingual width of 4 mm, a gingival step width of 2 mm, and a depth of 5 mm, 1 mm above the enamel-cementum junction. Cavity dimensions were standardized by measuring with a periodontal probe. The 150 prepared cavities were randomly divided into 5 groups and then into 3 different subgroups. Ten samples were used in each subgroup.

Restoration of cavities

The Palodent V3 Segmented Matrix System (Dentsply, USA) with pre-contoured metal bands was used for the restoration of the cavities. After the matrix band (5.5 mm) was placed, a special wedge of the matrix system (medium) and then a metal ring to keep the matrix stable was placed (Figure 1).

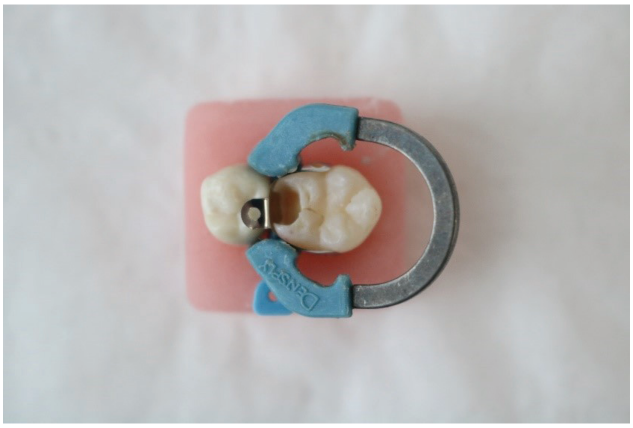


Figure 1. Placement of the matrix system before restoring cavities.

After the matrix system was placed, the restorations were made using 3 different layering techniques and 5 different LED light devices by a single investigator and in line with the recommendations of the manufacturers (Table 1). After that, the samples were kept in distilled water.

In this study, three different third-generation (Valo Cordless, Ultradent, USA; Bluephase N, Ivoclar Vivadent, Liechtenstein; D-Light Pro, GC, USA) and two different second-generation (SmartLite Focus, Dentsply, USA; Led.E, Woodpecker, China) LED light devices were used (Table 2).

Table 1. LED light devices used in the study

Features Light Device	Generation	Wavelength	Light density
SmartLite Focus (SL) (Dentsply, USA)	Second-generation	420-540 nm	1000 mW/cm²
Led. E (LE) (Woodpecker, China)	Second-generation	420-480 nm	1000-1200 mW/cm²
Valo Cordless (VC) (Ultradent, USA)	Third-generation	395-480 nm	Standard mode: 1000 mW/cm² High power mode: 1400 mW/cm² Extra power mode: 3200 mW/cm²
Bluephase N (BN) (Ivoclar Vivadent, Liechtenstein)	Third-generation	385-510 nm	High power mode: 1200 mW/cm² Low power mode: 650 mW/cm² Soft Start mode: 650–1200mW/cm²
D-Light Pro (DL) (GC, USA)	Third-generation	400-480 nm	High power mode: 1400 mW/cm² Low power mode: 700 mW/cm² Detection mode

Table 2. Composite resins used in the study

Features Composite	Organic matrix	Inorganic Filler	Filler rate (weight-volume)	Application thickness
Ceram.x SphereTEC one universal A2 (Dentsply, Germany)	Methacrylate modified polysiloxane, Bis-GMA, TEGDMA	Barium-aluminium-borosilicate glass, Ytterbium fluoride	50-73 %	2 mm
SDR flow+ A2 (Dentsply, Germany)	Modified UDMA, EBPADMA TEGDMA	Barium-aluminum fluoroborosilicate glass Strontium-aluminum fluorosilicate glass	43-65 %	4 mm

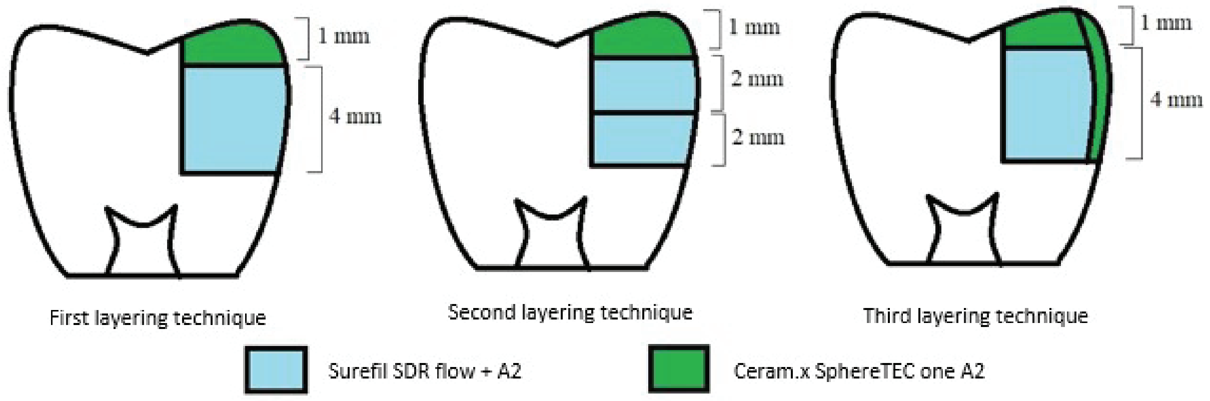


Figure 2. Layering techniques used in the study

The first layering technique (Bulk fill technique): After 4 mm thick bulk fill composite resin (SDR (Smart Dentin Replacement) flow+ A2, Dentsply, Germany) was applied, it was polymerized with a light device for 40 sec, then 1 mm thick nanoceramic composite resin (Ceram.x SphereTEC one universal A2, Dentsply, Germany) was applied over and polymerized for 20 sec (Figure 2).

The second layering technique (Horizontal layering technique): After applying 2 mm thick SDR, it was polymerized with a light device for 20 sec, and this application was repeated. Finally, 1 mm thick Ceram.x was applied and polymerized for 20 sec.

The third layering technique (Centripetal buildup technique): The Ceram.x composite was first placed adjacent to the matrix surface with a thickness of approximately 0.5 mm, and the cavity was converted to a class I cavity and polymerized for 20 sec. Then, a 4 mm thick SDR was applied and polymerized for 40 sec. Lastly, 1 mm thick Ceram.x was applied and polymerized for 20 sec.

The samples were kept in distilled water at 37 °C for 24 h. All samples were polished with Sof-Lex (3M, USA) polishing discs renewing in every 5 samples.

Aging by thermal cycle

After the polishing process, the samples were placed in a thermal cycle device (THE-1100, SD Mechatronics, Germany) in heat baths between 5 ± 2 ºC and 55 ± 2 ºC, with a dwelling time of 30 sec at each temperature and a transfer time of 10 seconds. Samples were subjected to thermal cycles 1500 times.

Scoring of microleakage

All specimens were coated with two coats of nail varnish at a distance of 1 mm from the restoration margins. After the nail polish dried, it was kept in 0.2% methylene blue solution at 37°C for 24 h. After 24 h, the teeth were washed under water to allow excess paint to flow. The restorations were divided into two equal parts in the mesiodistal direction with a precision cutting device (IsoMet 1000, Buehler, USA) under water cooling.

The amount of gingival and occlusal microleakage of the obtained cross-section samples was examined with a stereomicroscope (Leica MZ 75, Germany) at x25 and x40 magnification. Photographs were taken from each sample. Dye penetration grades were scored according to the criteria shown in Table 3. Occlusal and gingival microleakage scores of each sample were evaluated by two investigators.

Table 3. Microleakage scoring criteria15

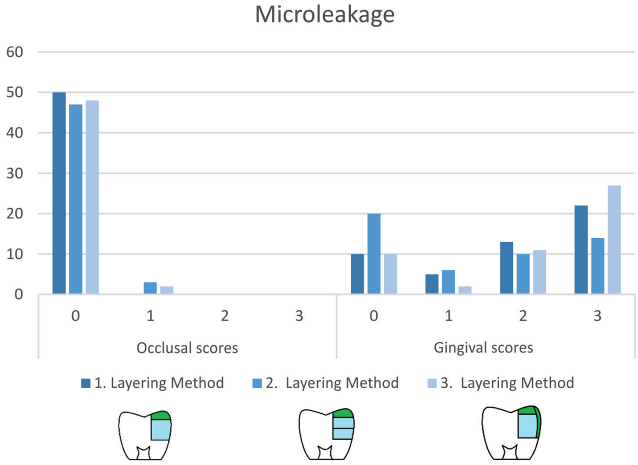
Score	**Microleakage in the Occlusal Region**	**Microleakage in the Gingival Region**
0	No dye penetration	No dye penetration
1	Dye penetration up to half of the occlusal wall	Dye penetration up to half of the gingival wall
2	Dye penetration exceeding half of the occlusal wall	Dye penetration exceeding half of the gingival wall
3	Continued dye penetration into the pulp	Dye containing the gingival and axial wall and continuing into the pulp

Statistical analysis

The data obtained in this study were analyzed using the Stata 15.1 program. Kruskal-Wallis analysis method was used to compare more than two independent groups. In case of difference between groups, the Mann Whitney U test was used for pairwise comparisons. The p-value less than 0.05 was accepted as the statistical significance level.

Results

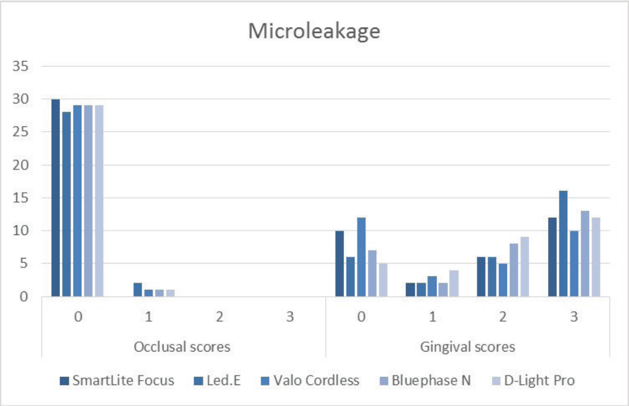
According to the Kruskal-Wallis analysis, when the layering methods were compared, the group with the highest microleakage was the third layering method (centripetal buildup), and the group with the least microleakage was the second layering method (horizontal layering). However, there was no statistically significant difference between the groups (p>0.05) (Graphic 1).



Graphic 1. Comparison of microleakage scores in the occlusal and gingival regions according to layering techniques.

Although there was no difference between the application techniques in the occlusal region in terms of microleakage, the most successful technique was the first technique and all samples scored 0. Samples that scored 0 and 1 in the gingival region were 52% in the second layering method, 30% in the first layering, and 24% in the third layering method.

When light devices are compared; in the gingival area the light device with the most microleakage was Led.E, and the light device with the least microleakage was Valo Cordless. However, no significant difference was observed between the groups (p>0.05) (Graphic 2).



Graphic 2. Comparison of microleakage scores in the occlusal and gingival regions according to light devices

In the occlusal region, a score of 0 was observed in all samples, except for one score of 1 in the LE-2, LE-3, VC-2, BN-3, and DL-2 groups. Significantly less microleakage was observed in the occlusal region compared to the gingival region (p=0.00) (Table 4).

Table 4. The number of samples scored according to microleakage evaluation

Scores / **Groups**	**Occlusal**				**Gingival**			
	0	**1**	**2**	**3**	**0**	**1**	**2**	**3**
SL-1	10	0	0	0	5	1	1	3
SL-2	10	0	0	0	4	0	3	3
SL-3	10	0	0	0	1	1	2	6
LE-1	10	0	0	0	1	2	2	7
LE-2	9	1	0	0	5	2	1	2
LE-3	9	1	0	0	0	0	3	7
VC-1	10	0	0	0	2	2	4	4
VC-2	9	1	0	0	6	1	0	3
VC-3	10	0	0	0	6	0	1	3
BN-1	10	0	0	0	2	1	3	4
BN-2	10	0	0	0	3	0	3	4
BN-3	9	1	0	0	2	1	2	5
DL-1	10	0	0	0	2	1	3	4
DL-2	9	1	0	0	2	3	3	2
DL-3	10	0	0	0	1	0	3	6

In the occlusal area, 96.67% of all samples scored 0, while 3.33% scored 1 according to microleakage. The most successful light device was found SmartLite Focus (SL). In the gingival area, regardless of which type of light device and which layering technique is used, 26.67% of the samples had scored 0, 8.67% scored 1, 22.67% scored 2 and 42% scored 3. In the gingival area, the most score of 3 was observed in LE-1 and LE-3 groups, following SL-3 and DL-3. VC-2 and VC-3 groups showed less microleakage following SL-1 and LE-2 groups.

Discussion

During the polymerization of the composite, approximately 1-5% volume change occurs[10]. Polymerization shrinkage causes stress at the interface between tooth and restoration as the elastic modulus of the composite increases during polymerization. As a result of these stresses; bond rupture, tubercle movements, microcracks in the enamel, secondary caries, and pulpal irritation due to bacterial leakage may occur which cause postoperative sensitivity[16-18]. Methods such as increasing the inorganic filler ratio and making changes in the organic matrix have been reported to reduce polymerization shrinkage. In addition, the use of high molecular weight monomers in the organic matrix also reduces polymerization shrinkage[17,18]. One of the most investigated bulk-fill composites in terms of shrinkage stresses was SDR. The photoactive group associated with the modified UDMA monomers has been claimed to function as a polymerization modulator. The high molecular weight polymerization modulator with this stress-reducing resin technology allows the monomers to combine more flexibly during conversion to polymer, thus resulting in a higher conversion rate[19,20]. Different layering methods can be used to reduce the C factor. A thin layer of a flowable composite can be placed on the base to absorb the stresses[21,22]. Moreover, soft-start techniques of light devices might be used to reduce polymerization shrinkage[23].

Microleakage is an inevitable consequence of polymerization shrinkage in composite restorations. Some studies have found a positive relationship between shrinkage stresses and microleakage tests[11,12]. Composite resin restorations are the most commonly used restorative materials in the restoration of Class II cavities, as they can be bonded to the teeth as adhesive, support the remaining tooth tissue, are aesthetically preferred by patients, and are resistant to chewing forces[24,25]. Especially considering the problems in the gingival region of deep Class II adhesive restorations, it can be concluded that the problems caused by microleakage are often in these cavity types and in the gingival step[26,27]. In this study, the effect of different layering methods and the use of different light devices on microleakage in Class II box cavities were evaluated.

One of the most important factors in reducing polymerization shrinkage stresses is the layering technique. Although some studies have proven that layering techniques reduce polymerization shrinkage, others have found no significant difference[21,22,28,29]. The bulk application technique, on the other hand, makes the treatment faster and simpler by reducing the number of clinical steps[30]. In this study, Class II box cavities prepared in extracted teeth were restored with three different layering methods and polymerized with five different light devices. Led.E light device showed the most microleakage among the light devices, and Valo Cordless light device was the group with the least microleakage, and no significant difference was observed between the groups. In the layering methods, the group showing the most microleakage was the third layering (centripetal) method, and no significant difference was found between the groups. The centripetal technique may give different results in clinical conditions, the results of the study may be due to the application in *in vitro* conditions. Increasing the number of samples might be beneficial to demonstrate the difference between layering techniques. In the present study, 10 samples for each group were used, however, the number of samples was not enough to differentiate the effects of layering techniques on microleakage despite power analysis.

Chandurkar *et al*. subjected Class V cavities to extracted teeth to microleakage test after restoration with two different light devices (Spectrum 800 Dentsply; Bluephase, Ivoclar Vivadent) and two different polymerization modes. As a result of the study, the least microleakage was observed in the LED light device group in soft-start mode. The most microleakage was detected in the Quartz-Tungsten-Halogen (QTH) light device group used in standard mode. There was no statistically significant difference between the soft-start and standard modes of the LED and QTH groups[31].

Soares *et al*. prepared Class II cavities in bovine teeth for microleakage detection and restored them with nanofill composite (Filtek Z350, 3M ESPE) using three different light devices. As a light device; QTH (XL 3000, 3M ESPE), a second-generation LED light device (Bluephase 16i, Ivoclar Vivadent), and a third generation LED light device (UltraLume LED 5, Ultradent) were used. All light devices were applied for three different times 10, 20, and 30 seconds. As a result of the study, it was concluded that the polymerization time and the use of different light devices had no effect on microleakage[32]. Similar to their study in the present study second-generation light devices and third-generation light devices showed no statistical difference in terms of microleakage. The wavelength of the light devices might be considered to have no effect on polymerization. The composite resins used in the study do not have suitable photopolymerization initiators for third-generation light devices. All light devices used in the present study are of good quality and their light intensities are acceptable. Therefore, the use of third-generation light devices did not create an advantage for the composites used in the study.

In a study conducted by Kumar *et al.,* microleakage was examined in Class II cavities restored with a composite resin (Ceram.x mono M1, Dentsply) using three different layering methods (horizontal oblique, centripetal oblique, oblique). After restoration, the teeth were subjected to thermal cycle treatment 500 times and kept in a 2% methylene blue solution. As a result of the study, it was reported that no layering method could completely eliminate the microleakage, and the least microleakage was seen in the centripetal oblique method. No significant difference was observed between the horizontal oblique and oblique methods[33]. Habib and Waly studied the degree of conversion of different composite resins and different layering techniques, and microleakage in Class II box cavities. In their study, a nanofill composite (Z350 XT, 3M ESPE), a flowable bulk fill composite (Filtek Bulk Fill Flowable, 3M ESPE), a posterior bulk fill composite (Filtek Bulk Fill Posterior, 3M ESPE), and SonicFill Bulk Fill composite (Kerr) were used. While the degree of conversion differed between the groups, no significant difference was observed according to microleakage evaluation. These findings indicated that microleakage is not only dependent on the degree of conversion but is multifactorial[34]. In the present study using different layering techniques with bulk-fill composite (SDR) did not affect on microleakage of the restorations. Applying bulk-fill composite material with 2 mm layering was considered to decrease polymerization shrinkage and cause less microleakage, however, no statistical difference was found between layering techniques. It might be considered that applying bulk-fill composite with a 4 mm layer is time-effective.

Swapna *et al.* compared gingival and occlusal microleakages in class II cavities using three different bulk-fill composite resins (SonicFill, Kerr; Tetric Evo Ceram, Ivoclar Vivadent; X-trafil, Voco). They stated that the SonicFill group showed less microleakage in both the gingival and occlusal regions compared to the other groups. However, they concluded that the microleakage in the gingival region was significantly higher than the microleakage in the occlusal region in all composite resin groups[15]. Similar to their study, in the present study significantly less microleakage scores were obtained in the occlusal region than in the gingival region ($p=0.00$). It was thought that this might be due to the thinner enamel layer in the gingival region compared to the occlusal region.

Conclusions

Considering the data we obtained within the limitations of this study, we can extrapolate the following conclusions:

1. Among the different layering techniques applied to Class II box cavities, the least microleakage was observed in the group where SDR flow+ bulk fill composite was applied in 2 mm layers, and no significant difference was found between the groups.
2. Among the light devices, Led.E light device showed the most microleakage, Valo Cordless light device showed the least microleakage, and it was observed that the use of different light devices did not make a significant difference in microleakage.

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Conflict of Interests: Nothing to declare.

Financial Disclosure Statement: Nothing to declare.

Human Rights Statement: All the procedures on humans were conducted in accordance with the Helsinki Declaration of 1975, as revised 2000. Consent was obtained from the patient/s and approved for the current study by national ethical committee.

Animal Rights Statement: None required.

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