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Effect of Composite Resin Volume and Rapid Curing on Microleakage of Composite Restorations

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Research Article

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ABSTRACT

Objectives: The aim of this in-vitro study is to evaluate the effect of composite volume and rapid curing on microleakage of composite restorations.
Materials and Methods: 168 bovine incisors were randomly divided into 12 groups. Round cavities of 3 different diameters (2, 3 and 4 mm) and 2 different depths (1 and 2 mm) were prepared in the middle of the buccal surfaces of the teeth. The cavities were restored with a 7th generation adhesive system and micro-hybrid composite resin. Six of the groups were cured at 1000 mW/cm^2 light power, while the other 6 groups were cured at 3200 mW/cm^2. The restored teeth were immersed in 1% methylene blue solution for 24 hours. Then, the teeth were cut vertically to pass through the center of the restorations. The amount of microleakage was examined under a microscope. Data were analyzed with two-way Anova, Tukey and t tests ($p = 0.05$).
Results: The highest average microleakage scores at the incisal margin were observed in the 3x2 mm sized cavities cured at 3200 mW/cm^2 light power and in the 4x2 mm sized cavities cured at 1000 mW/cm^2 light power (mean score = 0.86, $p > 0.05$). The highest mean microleakage score at the gingival margin was observed in the 3x2 mm sized cavities cured at 1000 mW/cm^2 light power (mean score: 1.43, $p > 0.05$).
Conclusions: Considering the Pi value as 3.14, rapid polymerization of composite restorations with 3200 mW/cm^2 power, a volume of 3.14 mm^3 to 25.12 mm^3 does not affect microleakage.

Keywords: Composite, composite volume, curing, LED curing device, microleakage.

Kompozit Rezin Hacmi ve Hızlı Polimerizasyonun Kompozit Restorasyonların Mikrosızıntısı Üzerine Etkisi

Araştırma Makalesi

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ÖZ

Amaç: Bu in-vitro çalışmanın amacı, kompozit restorasyonların hacminin ve hızlı polimerizasyonunun mikrosızıntı miktarı üzerine etkisini değerlendirmektir.
Gereç ve Yöntemler: Çalışmada 168 adet sığır kesici dişi rastgele 12 gruba ayrılmıştır. Dişlerin bukkal yüzeylerinin ortasına, 3 farklı çapta (2, 3 ve 4 mm) ve 2 farklı derinlikte (1 ve 2 mm) yuvarlak kavite hazırlanmıştır. Kaviteler, yedinci nesil adeziv sistem ve mikro-hibrit kompozit rezin ile restore edilmiştir. Grupların altısı 1000 mW/cm^2 ışık şiddeti ile, diğer altı grup ise 3200 mW/cm^2 ışık şiddeti ile polimerize edilmiştir. Restorasyon işlemi tamamlanan dişler, %1'lik metilen mavisi çözeltisine 24 saat süreyle daldırılmıştır. Ardından, dişler restorasyonun merkezinden geçecek şekilde dikey olarak kesilmiştir. Mikrosızıntı miktarı mikroskop altında incelenmiştir. Veriler iki yönlü ANOVA, Tukey ve t-testi ile analiz edilmiştir ($p = 0.05$).
Bulgular: İnsizal kenarda en yüksek ortalama mikrosızıntı skorları, 3200 mW/cm^2 ışık şiddetiyle polimerize edilen 3x2 mm boyutundaki kavitelerde ve 1000 mW/cm^2 ile polimerize edilen 4x2 mm boyutundaki kavitelerde gözlemlenmiştir (ortalama skor = 0.86, $p > 0.05$). Gingival kenarda ise en yüksek ortalama mikrosızıntı skoru, 1000 mW/cm^2 ışık şiddetiyle polimerize edilen 3x2 mm boyutundaki kavitelerde gözlenmiştir (ortalama skor: 1.43, $p > 0.05$).
Sonuç: Pi değeri 3.14 olarak kabul edildiğinde, 3.14 mm^3 ile 25.12 mm^3 arasında değişen hacimlerdeki kompozit restorasyonların 3200 mW/cm^2 ışık gücüyle hızlı polimerizasyonunun mikrosızıntı üzerine anlamlı bir etkisi bulunmamıştır.

Anahtar Kelimeler: Kompozit, kompozit hacmi, polimerizasyon, LED ışık cihazı, mikrosızıntı.

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Introduction

Composite resin materials are frequently used for direct restoration in restorative dentistry. The polymerization procedures of these materials must be carried out using proper techniques. The conversion rate of composite resin materials from monomer to polymer is called as degree of conversion (DC) and should not be less than 55%. High DC contributes to all physical properties of the composite resin material.[1] However, shrinkage of composite resin materials during polymerization leads to stress accumulation between the tooth and restoration interface. These shrinkage stresses can cause cuspal deflection, microcracks, or micro-gaps between the dental filling.[2]

Some modifications can be made by manufacturers in the organic monomers of the composite resin materials to reduce the negative effects of polymerization shrinkage. However, clinicians can reduce the volume of composite used and therefore shrinkage stresses by placing cement base material at the base of the cavity in posterior teeth.[3] Another clinical method is to apply soft-start polymerization during curing. It has been stated that with the soft start polymerization procedure, the pre-gel phase is extended, and shrinkage stresses are reduced during the polymerization of the composite resin material. However, it is a fact that the results of previous studies on this subject are inconsistent.[4-6]

Curing time can be reduced by using higher power light polymerization devices during the curing process. The use of high-power polymerization devices may have negative effects on polymerization shrinkage stress.[7] However, it has also been shown that curing with high-power light devices does not affect microleakage in small cavities.[8] It is also known that cavity dimensions affect shrinkage stress and microleakage.[9]

Microleakage is defined as the passage of fluids, molecules, ions or bacteria between the cavity wall and the restorative material.[10] Microleakage can lead to restoration failures such as marginal discoloration, loss of retention, fracture, and secondary caries. The cause of microleakage is micro-gaps between the cavity wall and the restoration, which may also occur after polymerization shrinkage. These micro-gaps often cannot be detected clinically.[11] Also, cavity configuration factor, placement technique of the composite resin material, curing protocol and adhesive technique are other factors affecting polymerization shrinkage stresses and hence microleakage.[12]

The aim of this study is to compare the microleakage values of 6 different sized composite resin restorations. In addition, half of the restorations were cured with 1000 mW/cm^2 while the other half was cured with 3200 mW/cm^2. The null hypotheses of the study are:

- There is no difference between the microleakage values of composite resin restorations of different sizes.
- There is no difference between the microleakage values of composite resin restorations cured at different light powers.

Materials and Methods

Kırıkkale University Non-Interventional Ethics Committee approval was obtained (Decision No: 2025.01.04). For this study, 168 freshly extracted bovine incisors were obtained. The teeth were stored in distilled water at room temperature for less than three months and the surface debridement was performed. Then the teeth were randomly divided into 12 groups (n = 14).

Round-shaped cavities with 3 different diameters (2 mm, 3 mm, 4 mm) and 2 different depths (1 mm, 2 mm), were prepared in the middle of the buccal surfaces of each tooth using a green-banded fissure diamond bur (Meisinger, Hager & Meisinger GmbH, Neuss, Germany) with a high-speed device under water cooling by one clinician (M.H). When the pi number was calculated as 3.14, the volumes of the cavities were 3.14 mm^3, 6.28 mm^3, 7.065 mm^3, 14.13 mm^3, 12.56 mm^3, 25.12 mm^3, respectively.

The cavities were restored using a 7th generation adhesive system (Quadrant Uni-SE-Bond, Cavex, Haarlem, The Netherlands) and a micro-hybrid composite resin (Charisma Smart, Heraeus Kulzer GmbH, Hanau, Germany) according to the manufacturer's instructions by one clinician (E.T.T). The materials are shown in Table 1.

Table 1. The restorative materials used in the study

Material	Type	Composition	Lot No
Quadrant Uni-SE Bond (Cavex)	7th Generation Adhesive System	Urethane Dimethacrylate, 4- Methacryloxyethyl Trimellitanhydrid, Carboxylic acid based monomer, Amorphous silica, Camphoroquinone, Acetone, Distilled water.	10071
Charisma Smart (Kulzer GmbH)	Micro-hybrid composite	Bisphenol A-glycidyl methacrylate, Triethylene glycol dimethacrylate, trimethoxysilylpropyl methacrylate, methacrylic acid, Amorphous silica, barium aluminum fluoride glass filler	10534

During the making of the restorations, half of the groups were polymerized with a curing device (Valo Cordless, Ultradent, UT, USA) at 1000 mW/cm^2 power for 20 s and the other half with the same curing device at 3200 mW/cm^2 power for 6 s (for adhesive procedure 10 s at 1000 mw/cm^2, 3 s for 3200 mW/cm^2). Finishing and polishing procedures of the restorations were performed using a yellow band flame-tipped diamond bur (Meisinger, Hager&Meisinger GmbH, Neuss, Germany) and a composite polishing kit (CLEARFIL™ Twist DIA, Kuraray, Tokyo, Japan) by one clinician (E.A). The samples were stored in distilled water at 37°C for 24 hours. Before dye penetration, the apical foramens of all teeth were covered with sticky dental wax (Polywax, Bilkim Medical Products Company, Izmir, Türkiye) and two coats of nail polish were applied to all external surfaces up to 1 mm from the restoration margins. After that, the specimens were placed in 1% methylene blue solution for 24 hours and washed under tap water.

Then the specimens were cut at 450 rpm under water cooling with a diamond disc (Microcut, Metkon, Bursa, Turkey) parallel to the long axis of the teeth and passing through the center of the restorations.

All sections were viewed and photographed at x40 magnification under a stereo microscope (Zeiss OPMI Pico Tube f170, Carl Zeiss, Aalen, Germany). The amount of microleakage in the samples was evaluated by 2 researchers based on the photographs according to the following scores (Y.B and M.H).
0: No dye penetration.
1: Dye penetration through the gingival or occlusal wall to less than half the cavity depth.
2: Dye penetration through the gingival or occlusal wall to more than half the cavity depth but does not extend to the axial wall.
3: Dye penetration through the gingival or occlusal wall to the full cavity depth and extend to the axial wall.

Data were analyzed using two-way ANOVA, Tukey and t tests at 95% confidence intervals.

Results

No marginal adaptation problem was detected in any restoration after visual inspection. According to the results of two-way ANOVA, neither cavity volume ($p = 0.138$) nor light power ($p = 0.438$) significantly affected the gingival microleakage scores (Table 2).

The highest average microleakage score at the gingival margin was observed in the 3x2 mm sized cavities cured at 1000 mW/cm^2 light power (mean score = 1.43 ± 0.51). The lowest average microleakage scores at the gingival margin were observed in the 3x1 mm sized cavities cured at 1000 mW/cm^2 light power and 4x2 mm sized cavities cured at 3200 mW/cm^2 (mean score = 0.64 ± 0.63). However, no statistically significant difference was found between the groups in terms of average gingival microleakage scores ($p>0.05$).

Table 2. Two-way ANOVA results for gingival microleakage scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Cavity volume	4.101	5	0.820	1.698	0.138
Light power	0.292	1	0.292	0.604	0.438
Cavity volume*light power	4.244	5	0.849	1.757	0.125
Error	75.357	156	0.483		
Total	227.000	168			

The incisal microleakage results were also found to be not significantly affected by cavity volume ($p = 0.155$) or light power ($p = 0.498$, Table 3). The highest average microleakage scores at the incisal margin were observed in the 3x2 mm sized cavities cured at 3200 mW/cm^2 light power and in the 4x2 mm sized cavities cured at 1000 mW/cm^2 light power (mean score = 0.86 ± 0.66 for both groups). The lowest microleakage score at the incisal margin was observed in the 4x1 mm sized cavities cured at 1000 mW/cm^2 light power (mean score = 0.14 ± 0.36). However, there was no statistically significant difference was found between the average incisal microleakage scores ($p > 0.05$).

Figure 1. Two representative specimens that have higher microleakage scores at gingival region.

Table 3. Two-way ANOVA results for incisal microleakage scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Cavity volume	3.786	5	0.757	1.631	0.155
Light power	0.214	1	0.214	0.462	0.498
Cavity volume*light power	3.643	5	0.729	1.569	0.172
Error	72.429	156	0.464		
Total	142.000	168			

When the incisal and gingival microleakage results were compared within the groups, it was seen that the incisal microleakage value was significantly higher than the gingival microleakage value in four groups ($p < 0.05$) (Figure 1). In one group, the incisal and gingival microleakage values were found to be equal. The average incisal and gingival microleakage values within the groups are shown in Table 4.

Table 4. The mean, minimum and maximum microleakage scores of the groups (sd = standard deviation)

Groups	Incisale microlekage (mean ± sd)	Incisale min.-max. scores	Gingival microleakage (mean ± sd)	Gingival min.-max. scores	P value
2x1 1000 mW/cm^2	*0.57 ± 0.76*	*0-2*	*1.29 ± 0.83*	*0-2*	**0.025**
2x1 3200 mW/cm^2	*0.29 ± 0.47*	*0-1*	*0.86 ± 0.54*	*0-2*	**0.006**
2x2 1000 mW/cm^2	0.50 ± 0.52	0-1	0.86 ± 0.66	0-2	0.125
2x2 3200 mW/cm^2	0.50 ± 0.65	0-2	1.00 ± 0.78	0-2	0.078
3x1 1000 mW/cm^2	0.71 ± 0.73	0-2	0.64 ± 0.63	0-2	0.784
3x1 3200 mW/cm^2	0.64 ± 0.75	0-2	1.00 ± 0.96	0-3	0.282
3x2 1000 mW/cm^2	*0.64 ± 0.75*	*0-2*	*1.43 ± 0.51*	*0-2*	**0.003**
3x2 3200 mW/cm^2	0.86 ± 0.66	0-2	0.93 ± 0.62	0-2	0.770
4x1 1000 mW/cm^2	*0.14 ± 0.36*	*0-1*	*0.71 ± 0.73*	*0-2*	**0.016**
4x1 3200 mW/cm^2	0.79 ± 0.89	0-2	0.86 ± 0.66	0-2	0.812
4x2 1000 mW/cm^2	0.86 ± 0.66	0-2	0.86 ± 0.66	0-2	1.000
4x2 3200 mW/cm^2	0.79 ± 0.80	0-2	0.64 ± 0.63	0-2	0.605

Discussion

According to the findings of this study, the first null hypothesis was accepted. It was reported in a previous study that composite volume is directly related to the polymerization shrinkage stresses. Higher composite volume results in greater polymerization shrinkage stress.[13] Excessive polymerization shrinkage stresses either lead to cuspal deflection or micro-gaps between the restoration and the cavity walls. If micro-gaps occur, this leads to marginal microleakage.[14] In this study, the cavity volumes are relatively small and therefore, it can be considered that the cavity volume does not affect microleakage according to the findings of this study.

Gamarra et al. reported that the cavity margins are quite sound when the cavity is limited to enamel tissue and restored with a 6th generation adhesive system.[15] In this study all the cavity margins are limited to enamel tissue and the cavities were restored with a 7th generation adhesive system and no marginal adaptation problem was visually detected in any restoration. However, microleakage was detected in some restorations.

Costa Pfeifer et al.[16] reported that the microleakage of composite restorations cannot be predicted by considering the volume of the restoration alone. Also in large cavities, the preferred adhesive system is the most important factor in microleakage formation. In this study, no difference was found between the average microleakage values of composite restorations with volumes ranging from 3.14 mm³ to 25.12 mm³. However, all restorations were performed using the same adhesive system so there is no data available about the different adhesive systems effect on microleakage scores.

Braga et al.[9] reported that the average microleakage scores of cylindrical Class V composite restorations influenced both the diameter and the depth of the cavities. On the contrary, in our study, the depth and diameter of the prepared cavities did not affect the microleakage values of the restorations. However, in the study by Braga et al. the largest cavity dimensions were 6x2 mm, while in our study they were 4x2 mm.

According to the findings of this study, the second null hypothesis was accepted. There are no statistically significant differences between the average microleakage scores of the restorations that were cured at 1000 mW/cm^2 or 3200 mW/cm^2.

Curing composite restorations with a high-power light-curing device saves time to dentists. However, in rapid curing, the pre-gel phase is shortened, and this leads to more shrinkage stress and may increase the amount of microleakage. In a previous study, Atria et al.[6] reported that different curing modes (650 mW/cm^2, soft start with 650 to 1200 mW/cm^2, 1200 mW/cm^2 and 2000 mW/cm^2) did no influence the volumetric shrinkage of Class I composite restoration. Par et al.[7] reported that, polymerization shrinkage forces can occur in early stages of polymerization when using a high-power light curing device. In our study, the effect of rapid polymerization on microleakage of composite restorations was investigated and it was found that the average microleakage scores of restorations with volumes ranging from 3.14 mm to 25.12 mm were statistically similar. In a previous study, Demir and Bayraktar[8] also reported that different power densities did not affect the microleakage scores of small Class II composite restorations. Besides this, Braga et al.[9] reported for cylindrical cavities which were prepared in bovine incisors as in this study that microleakage scores were higher with increased depth and dimension.

In the four groups of this study, the average gingival microleakage scores were significantly higher than the mean incisal microleakage scores. In a previous study in which Class V cavities were prepared on the vestibule surfaces of bovine teeth and the marginal edges were limited by enamel tissue, Bayraktar and Hatırlı[17] reported that gingival microleakage scores were higher than incisal microleakage scores. Mazaheri et al.[18] reported that there was no statistical difference between incisal and gingival microleakage scores in teeth restored with glass ionomer. However, it was also reported that gingival microleakage was greater in cavities where the gingival margin ends in dentin tissue.[19] In our study, the cavity margins were limited to enamel. However, gingival microleakage values were statistically higher than incisal scores in the 4 groups.

Since methylene blue is smaller than bacteria, it can penetrate through areas that are too narrow for bacteria to penetrate.[20] However, the methylene blue solution is used in many microleakage studies because it is easy to prepare and low cost.[8,11,21,22] In our study, 1% methylene blue was used in accordance with the dental literature to detect microleakage. However, no incisal loading or thermal cycle were performed to the restorations. Furthermore, only the 7th generation adhesive system was used, and selective etching was not performed. Different adhesive systems were not used. Microleakage values were not investigated in cavities with larger volumes and at least one marginal edge ending in dentin. All these can be considered as limitations of the study.

Conclusions

Within the limitations of this study, no difference was found between the mean microleakage scores of composite restorations performed with a 7th generation adhesive system and a micro-hybrid composite with volumes ranging from 3.14 mm to 25.12 mm^2. Curing the restorations using an LED device with 1000 mW/cm^2 or 3200 mW/cm^2 light power also did not cause any difference between the mean microleakage scores. According to findings of this study, composite restorations with a cavity volume not exceeding 25.12 mm^2 and restored with a 7th generation adhesive system can be polymerized rapidly with a powerful LED curing device.

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The authors declare that they have no conflict of interest.

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