EFFECT OF CURING UNITS AND ADHESION STRATEGIES ON MICROLEAKAGE OF BULK-FILL COMPOSITES: AN IN VITRO STUDY

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ABSTRACT

Aim: This study was performed to investigate the effects of different light-curing units on microleakage of bulk-fill composites applied using different adhesion strategies (self-etch or selective etch).

Material and Methods: Twenty-six extracted third molar teeth were randomly divided into 2 groups (n=13) according to the light-curing units used: either a quartz tungsten halogen lamp or light-emitting diode lamp. Two standardized occlusal cavities (2×3×3 mm) were prepared on each tooth to create subgroups (self-etch or selective etch). Cavities in the electiveetch subgroup were etched prior to restoration procedures using 37% orthophosphoric acid. All cavities were then covered with a nano-filler bulk-fill composite resin using Universal Bond (All-Bond Universal; Bisco, Schaumburg, IL, USA) as an adhesive. The light activations were performed according to the light-curing units. Teeth were thermocycled 2500 times at 5°C–55°C, then immersed in 0.5% basic fuchsin solution for 24 hours. Microleakage was quantitatively assessed using the dye-penetration method along with quantitative computer-aided image measurement. Data analysis was performed using the Mann–Whitney U test.

Results: The selective etch group had significantly lower microleakage measurements than the Universal Bond group (p<0.05) in both the quartz tungsten halogen lamp and light-emitting diode lamp curing groups. However, there was no significant difference between the self etch and selective etch subgroups according to the light-curing units used (p>0.05).

Conclusions: The selective etch method provides better adhesion when bulk-fill composites are used regardless of the light-curing units being used.

Keywords: Bulk-fill composites, LED, self-etch technique, selective etch technique, QTH.

ÖZ

Amaç: Bu çalışma, farklı ışık-polimerizasyon ünitelerinin farklı adhezyon stratejileri (self-etch veya selektif etch) kullanılarak uygulanmış kütleSEL işıklanabilen kompozitlerin mikrosızıntıları üzerindeki etkilerini araştırarak amaçlamaktadır.

Gereç ve Yöntem: 26 adet çiğnemeli üçüncü molar diş, kullanılan ışık-polimerizasyon ünitelerine göre quartz tungsten halojon (QTH) veya ışık yayan diyet (LED) olmak üzere 2 gruba (n=13) ayrıldı. Alt grupları oluşturmak amacıyla (self-etch(SE) veya selektif etch(SLE)) her diş üzerindeki standart okuluz kavite (2×3×3 mm) hazırlanı. SLE alt grubundaki kaviteler, %37’lik ortofosforik asit kullanılarak restorasyon benzetimlerinden önce hazırlanı. Tüm kavittel daha sonra Universal Bond (All-Bond Universal; Bisco, Schaumburg, IL, USA) anaj anaj kullanılarak bir nano doldurucu kütleSEL işıklanabilen kompozit rezine restore edildi. Işık aktivasyonları alt oldukları grubun ışık-polimerizasyon ünitelerine göre yapıldı. Dişler, 5 °C-55 °C de 2500 kez termal döngü tabi tutuldu daha sonra 24 saat boyunca %0.5 bazik füksin çözeltisinde bekletildi. Mikrosızıntı, boya-penetrasyon yöntemi kullanılarak, bilgisayar destekli görüntü ölçümleri ile kantitatif olarak değerlendirildi. Veri analizi Mann–Whitney U testi kullanılarak yapıldı.

Bulgular: Selekty etch (SLE) grubu için hem quartz tungsten halojon hem de ışık yayan diyet gruplarında Universal Bond grubuna göre (p<0.05) anlamli derecede düşük mikro-sızıntı ölçümleri bulguladı. Bununla birlikte kullanılan ışık-polimerizasyon ünitesi için ise self-etch ve selektif etch alt grupları arasında anlamli fark görülmedi (p>0.05).

Sonuç: SLE yöntemi, kullanılan ışık çiğnemeleri bağımsız olarak kütleSEL olarak işıklanabilen kompozitler kullanıldığında daha iyi bir adezyon sağlamıştır.

Anahtar Kelimeler: Bulk-fill kompozitler, LED, self-etch tekniği, selektif etch tekniği, QTH

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INTRODUCTION

The use of direct resin-based composite (RBC) restorations has increased with the demand for minimally invasive treatments and tooth-colored restorations. However, the placement of a direct RBC restoration requires sensitive operative techniques to achieve success. Every step of the technique, including the bonding procedures, placement of the composite into the cavity, and curing, present a series of challenges that the clinician must overcome to ensure high-quality, long-lasting restorations.

Direct composite resin restorations are generally placed in increments of 2 mm². However, there are some issues with this method. One issue is that it is time-consuming and associated with the development of voids and porosity, especially in deep posterior cavities. Bulk-fill composites were therefore introduced to overcome this problem of conventional RBCs. Bulk-fill composites have low volumetric polymerization shrinkage hence can be used in thicknesses of up to 4 mm in one increment, resulting in low polymerization shrinkage stress.

Choosing an adequate adhesive system is one of the most important factors in restoration success. However, this is a fairly difficult task because many alternatives are available on the market. Two main adhesive systems are currently in use: the etch-and-rinse method and the less time-consuming self-etch (SE) method. Both methods are considered to provide adequate dentin bonding; however, the etch-and-rinse method is more effective for enamel bonding.

A new-generation adhesive system was recently introduced as a “universal” or “multi-mode” adhesive. This system is basically a one-step SE adhesive that can also be used with phosphoric acid (selective etch [SLE]). This versatile bonding system enables the practitioner to choose the best-suited method for each single cavity.

Another important aspect of direct composite restorations is the light-curing unit (LCU) that is used. The most commonly used LCUs are quartz tungsten halogen (QTH) lamps, which are still considered the gold standard for photopolymerization. However, QTH LCUs have limitations, such as the need to replace the fans and optical filters, short lifetime, and relatively long exposure time. Light-emitting diode (LED) LCUs have been developed to overcome these problems.

The effects of different LCUs and polymerization strategies on bulk-fill composites have not been thoroughly investigated, especially with respect to microleakage. Microleakage does not influence the development of secondary caries in the short term, but the loss of marginal integrity due to microleakage leads to interfacial gap formation and subsequent biofilm formation around sealant margins, which may in turn initiate the development of caries lesions. In the present study, the effect of different adhesive and polymerization strategies on the microleakage of newly developed bulk-fill RBCs was investigated. The null hypothesis was that the choice of LCU and adhesion protocol would not affect the level of microleakage around bulk-fill restorations.

MATERIALS AND METHODS

This study was approved by the Baskent University Institutional Review Board (project No. D-DA16/03) and supported by the Baskent University Research Fund.

Twenty-six extracted third molar teeth free from caries, cracks, and hypoplastic defects were used in the study. The external debris was removed from the teeth with a hand-scaler and cleaned using pumice before cavity preparation. The teeth were stored in distilled water for a maximum of 1 month, and the water was changed weekly to prevent bacterial growth. Cavities were prepared using diamond burs (Meisinger, Neuss, Germany) under a water-cooled high-speed handpiece (Slient Power 4L; Castellini, Imola, Italy). Two standardized occlusal cavities (2×3×3 mm) were prepared on each tooth. The teeth were then randomly divided into two groups according to the curing protocol used (n=13). The outputs of the curing lights were 600 mW/cm² (Hilux) and 1200 mW/cm² (Elipar S10). For each tooth, one of the cavities was randomly chosen for the SE or SLE method.

Group A: QTH (Hilux; Benlioglu Dental, Ankara, Turkey)

Following the cavity preparations, the teeth were washed thoroughly with water spray, and excess water was gently removed with air spray. Each cavity was restored according to the adhesion protocol.

SE Group (Cavity 1)

Two separate coats of Universal Bond (All-Bond Universal; Bisco, Schaumburg, IL, USA) were
applied by scrubbing the preparation with a microbrush for 10 to 15 seconds per coat. Next, the excess solvent was removed by thoroughly air-drying with an air syringe for at least 10 seconds and then light-cured for 20 seconds with a QTH LCU. The cavities were restored with a nano-filled bulk-fill composite resin (Filtrek Bulk Fill; 3M ESPE, St. Paul, MN, USA) in one increment, then light-cured for 40 seconds with the QTH LCU.

**SLE Group (Cavity 2)**
As the first step of the restoration, cut and uncut enamel were etched for 15 seconds using 37% orthophosphoric acid. The rest of the procedures were performed as described for the SE Group.

**Group B: LED lamp (Elipar S10; 3M ESPE)**
Following the cavity preparations, the teeth were washed thoroughly with water spray, and excess water was gently removed with air spray. Each cavity was restored according to the adhesion protocol.

**SE Group (Cavity 1)**
Two separate coats of Universal Bond (All-Bond Universal; Bisco) were applied by scrubbing the preparation with a microbrush for 10 to 15 seconds per coat. Next, the excess solvent was removed by thoroughly air-drying with an air syringe for at least 10 seconds, then light-cured for 10 seconds with an LED LCU. The cavities were restored with a nano-filled bulk-fill composite resin (Filtrek Bulk Fill; 3M ESPE) in one increment, then light-cured for 20 seconds with the LED LCU.

**SLE Group (Cavity 2)**
As the first step of the restoration, cut and uncut enamel were etched for 15 seconds using 37% orthophosphoric acid; the rest of the procedures were performed as described for the SE Group. Finishing and polishing were performed using a Sof-Lex Finishing and Polishing System (3M ESPE).

**Microleakage evaluation**
The conventional dye-penetration method along with quantitative measurement was used to test the amount of microleakage. The teeth were subjected to thermocycling (2500 times at 5°C–55°C) with a 15-second dwell time and 10-second transfer time following the finishing of restorations. The tooth surfaces were coated with two layers of nail varnish (Maybelline, New York, NY, USA) up to 1 mm from the restoration margins after the thermocycling procedures. The samples were then immersed in 0.5% basic fuchsin solution (Wako Pure Chemical Industry, Osaka, Japan) for 24 hours. Thereafter, the samples were thoroughly rinsed under tap water until no dye was observed, air-dried, and embedded in epoxy resin (Struers, Copenhagen, Denmark). A parallel longitudinal section was made through the occlusal surfaces in the mesio-distal direction using a water-cooled low-speed diamond saw (Isomet; Buehler, Lake Bluff, IL, USA). Each section was digitally photographed using an X20 (1280×1024 resolution) under a stereomicroscope (Olympus, Tokyo, Japan). The images were transferred to a Macintosh computer in TIFF format. Open-source image analysis software (Image J, V.1.42; National Institutes of Health, Bethesda, MD, USA) was used to measure the extent of mesial and distal dye penetration along the enamel-restoration interface in millimeters. The microleakage value for each section was calculated by dividing the sum of the mesial and distal dye penetration values by the sum of the lengths of the mesial and distal enamel-restoration interfaces as described by Cehreli et al. The measurements were made by a single calibrated operator (B.C.) blinded to the test groups. The microleakage value for each specimen and for each tooth and subgroup were calculated as the mean±standard deviation.

**Statistical Analysis**
Data analysis was performed using SPSS for Windows, version 11.5 (SPSS Inc., Chicago, IL, USA). Normality of the continuous variable distribution was determined using the Shapiro–Wilks test. The Kruskal–Wallis test was used to evaluate homogeneity. The statistical significance of median values between two groups was evaluated using the Mann–Whitney U test, with p<0.05 considered statistically significant.

**RESULTS**
The quantitative data showed that the SLE group had significantly lower microleakage measurements than the SE group (p<0.05) in both the QTH and LED LCU groups. However, there was no significant difference between the SLE and SE groups according to the LCU used (p>0.05) (Table 1). The lowest microleakage scores were observed in the SLE+LED group, and the highest microleakage scores were observed in the QTH+SE group (Figure 1).
This study investigated the effects of different LCU and adhesion strategies on microleakage of bulk-fill composites. The results of the study showed no difference between the QTH and LED LCUs, and the SLE adhesion strategy performed better than the SE strategy; thus, our hypothesis was partly rejected.

Faria-e-Silva et al. investigated the effect of LCUs and the SE and total-etch techniques on the degree of conversion of bonding agents. Their results indicate that the impact of QTH and LED lights on the degree of conversion of bonding agents were depending on material and that the SE technique with the QTH performed more effectively. In the present study, we found no differences among the LCUs according to the bonding strategy used, but the products used differed between the present and above-mentioned studies; therefore, it may be misleading to further compare these studies.

Several studies have investigated the different polymerization properties of bulk-fill composites with LED LCUs. To the best of our knowledge, however, this is the first study to compare the effects of QTH and LED LCUs on the microleakage values of bulk-fill composite resins. Some studies are investigating the effect of LCU units on microleakage of different resin-based restorations.

Cehrel et al. investigated the effect of LEDs and QTH LCUs on microleakage of ormocer-based fissure sealants and found no difference among the LCU units used. Another study investigated the effects of QTH and LED LCUs on microleakage of resin-based fissure sealants and concluded that the microleakage values for the LED LCU was lower than that for the QTH LCU.

Zakavi et al. evaluated microleakage class II composite resin restorations cured with LED or QTH LCUs in vitro and showed that the LED LCU with different curing modes was more effective than the QTH LCU for reducing microleakage. Soares et al. investigated microleakage in Class V cavities restored with microhybrid composite resin with LED and QTH LCUs. The authors showed that among the cavities not submitted to thermal and mechanical load cycling, the QTH LCU showed lower microleakage than did the LED LCU. For those subjected to thermal and mechanical load cycling, the QTH LCU showed lower microleakage than the LED LCU, but a statistically significant difference was only observed in one type of microhybrid composite used in the study.

Studies investigating the effects of QTH and LED LCUs on microleakage of resin-based materials have shown different results. However, the present study is the first to investigate these effects on bulk-fill composites and demonstrated no significant difference between the two LCU units used in this study.

Takamizawa et al. investigated whether the use of total-etch or SE for different brands of universal bonds would have an impact on the bond strength and fatigue strength of the adhesives to dentin. Their results showed that the bond strength of universal adhesives to dentin depends on the adhesive material being used. However, All-Bond Universal, which is the same brand used in the present study, showed greater bond strength when used in the total-etch mode. These findings might be considered to be in accordance with our results. In the present study, however, we chose the SLE method and thus only etched the enamel. This was because previous reports have suggested that when normal SE adhesives are used and dentin is pretreated with phosphoric acid, the resin components of the SE adhesive might not penetrate the exposed collagen network as expected; this could result in a lower bond strength in dentin. Even if the bond strength is not reduced, Hanabusa...
et al.\textsuperscript{26} showed that the adhesive interface appeared more vulnerable ultrastructurally to biodegradation when the dentin is etched prior.

Loguercio et al.\textsuperscript{27} investigated the performance of universal bonding systems using the SE, SLE, and TE methods with conventional RBC restorations for 36 months. Although their results showed no significant differences among the bonding strategies, the SE group showed the least effectiveness.

An \textit{in vivo} study by Loguercio et al.\textsuperscript{28} used different brands of universal bonds with different adhesion strategies (active SE, passive SE, and SLE). Their results revealed that when the universal bond is applied in active mode (meaning that while applying the adhesive, manual pressure is applied and a microbrush is scrubbed on the cavity), it performs better than when the adhesive is simply applied and then left alone (passive SE). The authors showed that active SE application of universal bond might be a good alternative to SLE in specific clinical situations. In the present study, we applied the universal bond by scrubbing the preparation with a microbrush, which is defined as active SE according to Loguercio et al.\textsuperscript{28}.

McHugh et al.\textsuperscript{29} investigated the microleakage of conventional and bulkfill RBC restorations either unbonded or bonded with universal bonding system. They concluded that not all conventional and bulkfill RBC showed similar microleakage scores used for same standardized cavities with standardized protocols, they suggest that the LCU may cause these differences and should be examined. However in the previous study we found no such differences between LCUs used in the study but we only tested one bulkfill composite.

The results of the present study showed that the adhesion strategy plays a more important role than does the photopolymerization protocol. However, it should be kept in mind that an important limitation of this study is the \textit{in vitro} tests performed while interpreting the clinical outcomes. We used thermocycling followed by immersion in basic fuchsin solution to evaluate the microleakage; however, the clinical environment has more parameters, such as isolation. Thus, an \textit{in vivo} study will provide further information about the performance of bulk-fill composites applied with different adhesion strategies and photopolymerized with different LCUs.

\section*{CONCLUSIONS}

Within the limitations of this study, the results revealed that the adhesion protocol is more effective than the LCU used for elimination of microleakage in bulk-fill composite resins. The SLE adhesion strategy seems to be the most effective approach for bulk-fill composite resin restorations.

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