DOES PREHEATING EFFECT THE MICROLEAKAGE OF BULK FILL COMPOSITE RESTORATIONS ?

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Abstract

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Research Highlights

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The most obvious result in this study was that the highest microleakage value was seen in the samples applied as soon as they were taken out of the refrigerator. Microleakage values decreased with increasing temperature. Within the results of this study, it can be suggested that the composite resins should not be used as soon as they come out of the refrigerator and should be heated before use for less microleakage.

Introduction

Introduction to dentistry by Rafael Bowen in 1957, composite resins changed the practice of dentistry and became one of the most important restorative materials (Bowen, 1956; D'amario et al., 2013). In today's dentistry, composite resins have become one of the most frequently used materials in both anterior and posterior restorations because of the increasing concern and esthetic demands of patients against mercury-containing amalgam restorations (Papacchini et al., 2007). However, one of the major shortcomings of conventional composite resins is that polymerization is difficult, and polymerization shrinkage in deep cavities due to limited light penetration in posterior restorations. The resultant polymerization shrinkage stress manifests clinically with several clinical complications such as cusp deflection, microcracking and fracture of enamel margins, microleakage, debonding, postoperative sensitivity, and pulpal irritation (Cho et al., 2013; Ferracane & Mitchem, 2003; Loguercio et al., 2017).

To overcome these problems, an incremental technique for placing composite resins has been introduced. This technique provided proper light polymerization of the composite resin and reduced the polymerization shrinkage stress (Kim & Park, 2011; Kwon et al., 2012). The incremental technique has been used in the polymerization of the posterior teeth for a long time, but it has some disadvantages such as long process time, gaps between layers, and risk of contamination.

In recent years, the use of the composite resins for the restoration of posterior teeth has improved (Baroudi & Mahmoud, 2015; Eman M et al., 2016). However, concerns still remain with their use in high stress areas. The high viscosity and adhesiveness of these materials make it difficult to fit and adapt to the cavity walls. Poor adhesion between dentin and restorative material causes gap formation (Swapna et al., 2015). Ultimately, marginal cavity formation leads to microleakage that might be responsible for increased postoperative sensitivity, pulpal inflammation, discoloration, and recurrent caries (Kidd, 1976; Lohbauer et al., 2005). Material adaptation to the cavity walls is essential for a perfectly sealed, long-lasting restorations (Choudhary et al., 2011; Uctasli et al., 2008).

To compensate for these problems, recently, heating composite resins before polymerization has been proposed (Lohbauer et al., 2005; Nada & El-Mowafy, 2011; Wagner et al., 2008). Although the preheating process varies according to the brand of the material, the preheated composite resin showed more fluidity. In addition, composites polymerized at high temperatures increased the curing rate and degree of conversion. This can result in improved mechanical properties.

Seeking methods that are less sensitive to removing these disadvantages and placing techniques have resulted in the introduction of bulk-fill composite resins that can be placed and photopolymerized in a single layer with a thickness of 4–8 mm (Bucuta & Ilie, 2014).

Some changes have been made to the chemistry, particle size, and shape of the monomers to allow these materials to be used in bulk. While some of the bulk-fill composites are produced as a posterior restorative material, some are produced to be used as base materials to be covered with composite resin (Al-Harbi et al., 2016).

The clinical success of composite restorations is highly dependent on polymerization and the degree of monomer conversion.

High-viscosity composites are very difficult to adapt to the cavity correctly, and gap formation might occur in the course of application. Therefore, more fluid composites with less filler were produced .[19]

One of the major limitations of direct composite resin restorations is the high polymerization shrinkage .[5] The C-factor, also known as the configuration factor, is the ratio of the bonded surface of the restoration to the non-bonded surface and is a factor that affects polymerization shrinkage. Only the non-bonded surfaces of a restoration can act as a reservoir for plastic deformation during polymerization. Thus, if the C factor can be reduced clinically, polymerization shrinkage can also be reduced (Yang et al., 2016).

Recent research has focused on heating composite resins to improve their properties. The different preheating devices and methods including Micerium Ena Heat conditioner, Calset Composite heater, Therma-flo and Microwave heating system have been used in dentistry (Arora et al., 2017).

Friedman defined a polymerization method in which a higher monomer conversion degree was obtained by heating the composite resin at 54–60 degrees prior to light activation (Freedman, 2003). It is seen that heating composite resins before photopolymerization increases the degree of conversion, decreases viscosity, and increases adaptation.

As the temperature increases, both the radical and monomer mobility of the composite resin increase, resulting in a higher rate of cross-linked polymer chains (Daronch et al., 2006).

With this increase in transformation, the mechanical and physical properties of the composite resin, such as better surface hardness and polymerization depth, increase. In addition, the composite, whose fluidity increases with preheating, increases its compatibility with the cavity walls, which causes a decrease in micro-leakage and a decrease in secondary caries in the restoration (D'amario et al., 2013). There are many studies on microleakage of preheated composite resins in dental literature. However, the microleakage studies with Class II bulk fill composite restorations close to cemento- enamel junction are limited. The null hypothesis of this study; Temperature of bulk fill composite resins before polymerization has no effect on microleakage.

Methodology

The study was approved by Ordu University Ethics Committee (2019 – 76). The sample size calculated per group was 10 sound molars with an alpha of 0.05 and a beta of less than 0.2 (power >80%). This study has five stages: cavity preparation, restoration placement, thermal cycle, dye penetration, and microleakage evaluation:

Cavity preparation

A total of 80 freshly extracted sound human molars were used in the study. The remaining connective tissue and calculus on teeth were removed by scaling and the teeth were stored in 0.1% thymol solution at room temperature until the study was carried out. Samples were prepared from 80 non-carious molar teeth stored in saline at room temperature. A total of 160 standardized Class II cavities on the mesial and distal parts of teeth were prepared under water cooling. The Class II cavities were prepared as 6mm depth, 3mm mesiodistal width, and 4mm bucco-lingual width. The gingival walls of cavities were located 1 mm above the cemento enamel junction. Cavity depths were measured using a periodontal probe.

Restoration placement

In the study, one high-viscosity bulk-fill composite Filtek One Bulk-fill Restorative and two flowable bulk-fill composites Estelite Bulk-fill Flow and Sdr Posterior Bulk-fill Flowable Base, were used.

A matrix band (SuperMat, KerrHawe, UK) was placed around the teeth for restorative procedures and was held by finger pressure against the gingival margin of the cavity. Clearfil SE-Bond (Kuraray, Okayama, JAPAN) was used for all restorations.

The gingival halves of the mesial Cl II cavities were restored with Estelite Bulk-fill Flow (Tokuyama, Tokyo, JAPAN) (3 mm dept) and the gingival halfs of distal Cl II cavities were restorated with SDR Posterior Bulk-fill Flowable Base (Dentsply, DeTrey, GERMANY) composite (3mm dept) and the remaining occlusal halves of the all cavity were restored with Filtek^{TM} One Bulk-fill Restorative. (3M, St Paul, MN, USA) (3mm dept). All composite restorations were aplicated by an operator at room temperature of 21°C in the same day. Schematic of the restoration procedure is shown in figure 1. The composites were applied at four different temperatures: 4 °C, room temperatures(21°C), 39 °C, and 55 °C.

For groups at 4 °C, composites were used as soon as they came out of the refrigerator. For the samples at 39 °C and 55 °C, composites were applied at the desired temperature in the Micerium Ena Heat composite heating device according to the manufacturer's recommendations. The device was used according to the manufacturer's recommendations. The composite resins were polymerized from the occlusal part of the cavities with a high-performance LED light device (Elipar^{TM}S10, 3M, Seefeld, Germany) for 20 s.

Batch numbers and their respective manufacturers of the bulk fill composite resins used in the study are shown in Table 1.

Thermocycling

The restored teeth were then stored in distilled water at 37°C for 24 hours to ensure polymerization. After 24 hours, the restored teeth were subjected to the thermocycle (MTE101 Thermocycling Machine, Esetron, Ankara, Turkey) and alternated between 5°C and 55°C water baths with a dwell time of 20 seconds and a rest time of 20 seconds for 1000 times.

Dye penetration

After the thermal cycle application, the root ends of the samples were covered with flowable composite to prevent the passage of methylene blue from the foramen apical and lateral canals into the pulp cavity. Next, two layers of nail polish were applied to all tooth surfaces, 1 mm closer to the restoration edges. The prepared samples were kept in 0.5% methylene blue dye for 24 h. The teeth were then rinsed under running water to remove residual paint and allowed to dry at room temperature. Afterward, the samples were cut into two parts by cutting in the mesiodistal direction under water cooling.

Evaluation of microleakage

The dye penetration depth in the sections was examined by a different researcher at a magnification of $\times$ 40 (1280x960 resolution) on a stereomicroscope (Olympus, Tokyo, Japan) and was quantitatively evaluated using the NIS Element D image analysis software. Occlusal and gingival microleakage amounts were measured in mm under the same magnification on stereomicroscope images. Examples of microleakage belonging to the groups are shown in figure 2 (A,B,C,D).

Statistical analysis

The data of the study were analyzed using SPSS 22.0 (SPSS, Inc., Chicago, IL, USA). The normality of the distribution of the data was tested using the Kolmogrov-Smirnov test, and the data were found to be normally distributed. The one-way ANOVA was used to compare the microleakage values of each composite resin at four different temperatures. The post hoc Tukey test was used to compare the data of the groups in pairs.

An independent-sample t-test was used to compare microleakage values of composites applied at four different temperatures in the gingiva. The threshold for statistical significance was set at $p < 0.05$.

Results

As a result of the comparison of the microleakage values of the Filtek One Bulk-fill Restorative at four different temperatures on the occlusal surface, a statistically significant difference was observed among the four temperatures ($p<0.05$). To determine which groups caused this difference, the difference between the 4°C–39 C (p = 0.013) and 4°C–55 C (p = 0.005) groups was found to be statistically significant in the comparison of the groups; the difference between 4°C–20 C (p = 0.208), 20 C–39 C (p = 0.216), 20 C–55°C (p = 0.113) and 39 C–55°C (p = 0.726) was not statistically significant. The highest microleakage value was observed at 4°C (1701.35 µm), while the lowest microleakage value was observed at 55°C (1385.88 µm). Mean microleakage depths, standard deviation values, and p-values for the groups are shown in Table 2.

In the comparison of microleakage values of Estelite Bulk-fill Flow applied in the gingival region at 4 different temperatures with the One way ANOVA test, the difference between the 4 groups was not statistically significant ($p> 0.05$); in the comparison of the groups in pairs with the post hoc TUKEY test, it was observed that there was a statistically significant difference between the 4°C–39 C (p = 0.030) and 4 C–55 C (p = 0.044) groups. Among all the groups of Estelite Bulk-fill, the highest microleakage value was observed at 4°C with an average of 2773.02 µm and the lowest value at 39 °C with an average of 2227.59 µm. Average microleakage depths, standard deviation values, and p-values for groups are shown in Table 3.

When the results of the comparison of the microleakage values of SDR Posterior Bulk-fill Flowable Base applied in the gingival at four different temperatures with the one-way ANOVA test were examined, the difference between the four temperatures was found to be statistically 0.005). When the average microleak depths were examined, the highest microleakage value was observed at 4°C with an average of 2792.49 µm, and the lowest value was observed at 2079.23 µm, at 55°C. The difference was statistically significant at 4°C–20 C (p = 0.007), 4 C–39 C (p = 0.008) and 4°C–55 C (p = 0.000) in the post hoc Tukey test while It was observed that the difference between the 20 C–39 C (p = 0.980), 20 C–55 C (p = 0.282), and 39 C–55 C (p = 0.271) groups was not statistically significant. Average microleakage depths, standard deviation values, and p-values for the groups are shown in Table 4.

As a result of the comparison of microleakage depths of the Estelite Bulk-fill Flow and SDR Posterior Bulk-fill Flowable Base applied in the gingival with the independent t-test, no statistically significant difference was found between the tok composites at four different temperatures (p¿0.05). The average microleakage depths, standard deviation values, and p-values of the groups are observed in Table 5.

Discussion

Microleakage test is the one of evaluating methods the sealing efficiency of restorative materials (Taylor & Lynch, 1992). In the current study, the microleakage of different types and different temperatures of bulk-fill composites compared. As a result of our study, our null hypothesis that the prepolymerization temperature of bulk fill composite resins has no effect on microleakage was rejected.

Preheating is performed by placing composite resin tubes or syringes in a heating device (Arora et al., 2017). The use of this method resulted in a simplified placement and an increased adaptation to the cavity walls compared to resins used at room temperature. The preheated composite resin provides higher monomer conversion even with less energy and allows the irradiation time to be reduced by up to 75% (Moustafa et al., 2020). By heating the material before polymerization, its fluidity can be increased without sacrificing the amount of inorganic filler, and its marginal adaptation, physical and mechanical properties can be increased. This will result in a reduction in microleakage (Freedman, 2003).

There are many studies in the literature on microleakage in bulk-fill composite restorations (Alsagob et al., 2018; Behery et al., 2018; GARCÍA et al., 2019; Hoseinifar et al., 2020; Turkistani et al., 2020; Zajkani et al., 2022; Zotti et al., 2021) .

However, studies investigating the effect of preheating on the microleakage of bulk-fill composite resins are limited. Moustafa, M. N et al. reported that the bulk-fill composite preheated to 60^0 C (Filtek Bulk-fill) showed less microleakage than the same non-preheated composite resin and conventional composite (Filtek Z350) heated to 60degC (Moustafa et al., 2020).

The results of the study by Moustafa et al. are similar to those of our study. The lowest microleakage values of Filtek Bulk-fill Restorative applied on the occlusal surface, and Sdr Bulk-fill Flowable Base applied in the gingival were observed at 55degC, and the lowest microleakage value of Estelite bulk-fill flow applied in the gingival at 39degC. The highest microleakage value of all three composites was observed in samples used immediately after they were removed from the refrigerator (4degC).

Daronch et al observed in their studies that the increase in polymerization temperature increases the conversion of dimethacrylate monomers, but only up to a certain temperature limit. After this limit, the conversion of the monomer decreases with a further increase in temperature. It has been suggested that the reduction in monomer conversion is due to reactant evaporation and photoinitiator breakdown (Daronch et al., 2005).This might explain the monitoring of the lowest microleakage value of the Estelite Bulk Fill Flow composite applied to the gingival in our study at 39degC. The manufacturer does not have any data regarding this temperature limit of the Estelite Bulk-fill Flow composite used in our study. Therefore, more studies are needed to determine the accuracy of this result.

Yang J.N. et al., in their studies investigating the effect of preheating on microleakage in microhybrid composites (Heraeus Charisma(r) Smile), it was reported that the composite resin preheated at 50 degC showed the least microleakage (Yang et al., 2016).

Choudhary et al. The microleakage values of the nanofile universal hybrid composite Filtek Z350 (3M) and the condensable. Filtek P60 (3M) at room temperatures, 37 degC and 54 degC with restoration procedures similar to our study in class II cavities. Up to 54 degC, significantly lower microleak scores were obtained in both composite groups (Choudhary et al., 2011). These results are similar to the lowest microleakage value of SDR Posterior Bulk-fill Flowable base applied at the gingival in our study was observed at 55degC.

In a study conducted by Walter, it was reported that the heated resin lost approximately 50% of the increased temperature within 2 min after being removed from the device, and the loss was approximately 90% within 5 min. The rate of heat loss can be affected by placing it in the cavity preparation that can act as a heat sink (Walter et al., 2009).[34] In our study, the composites removed from the heating device were placed in the cavity as quickly as possible, but heat loss was inevitable. In Estelite Bulk-fill Flow, the lowest microleakage value is expected to be observed at 55 degC, as in other composites; one of the reasons for monitoring at 39degC might be the heat loss. In the results of our study, the difference between the 39degC–55degC groups was not found to be statistically significant for Estelite Bulk-fill Flow. (P¿0.05)

Given that the composite cools at a very rapid rate after removal from the warming unit, it seems advantageous to place the preheated composite quickly into the cavity to improve its performance, placing the capsule directly into the dispensing syringe during preheating, over preheating only the individual capsules themselves (D'amario et al., 2013).

It is recommended that the preheated composites are placed immediately as soon as the preheating process, without delay. This way, the positive effects of preheating in reducing microleakage could be monitored without the negative effects of delayed elastic deformation . Wagner et al. In their research where they cure preheated composite resin with a delay of 15 seconds; as expected, preheating resulted in the lowest microleakage. Delay curing was proposed to reduce the amount of thermal shrinkage that may occur if the heated composite is initially cured at high temperature. The highest microleak value was not expected in the group cured with a delay of 15 seconds, but the highest microleakage value was obtained in the delayed group. This can be explained by the fact that the 15 seconds delay allows the composite to move away from the cavity walls due to its visco-elastic behavior (Wagner et al., 2008).

Studies have reported that preheating does not reduce microleakage in composite restorations (Karaarslan et al., 2012).[35,36]This may be due to the sudden drop in the placement of the composite resin in the cavity .(Deb et al., 2011)[35] In our study, the composite resin heated in the Micerium Ena Heat device was placed in the cavity without waiting.

There are different results in the literature regarding microleakage of composite restorations. These different results found in studies might be due to the excess of factors affecting microleakage in laboratory studies.

Restorative material amount, cavity geometry, C factor, light source position and intensity, application of thermal aging, and mineral structure of teeth are factors affecting microleakage. In our study, to eliminate the deviations caused by these factors, a light source was applied to the cavities prepared with the same depth and width in such a way that they touched the matrix at the same distance in all samples. In addition, the same adhesive system was used in all samples, and the amount of restorative material was kept constant. Thermal cycles were applied at 5–55°C at 1000 cycles in all groups.

The mineral structure of the teeth is also one of the factors affecting the results of microleakage studies of composite restorations. The extracted teeth used in this study did not contain caries, discoloration, or fractures. However, micro defects that are formed in the cervical region during shooting, which are not visually noticeable, may cause an increase in microleakage values at the gingival edge.

Scoring methods are generally used to detect edge leakage in microleakage studies using dye penetration (Williams et al., 2002). However, thanks to recent developments in image analysis software, quantitative microleakage measurement methods have become more popular. In this study, images obtained at x40 magnification under the stereomicroscope instead of the traditional scoring method as a microleakage evaluation method were evaluated quantitatively using NIS Element D image analysis software.

Although it is not statistically significant in terms of microleakage between the fluid bulk-fill composites applied in the gingival, the current difference might be due to the differences in monomers, elasticity modulus, and filler particle ratios.

Conclusion

Based on the results of our study, preheating of bulk-fill composites as soon as carried out from the refrigerator could be a useful method of reducing microleakage.

However, more studies are needed to verify the accuracy of these results. Our study was carried out under in vitro conditions, and in vivo studies are needed to determine the advantages and disadvantages of preheating in clinical conditions.

Acknowledgments

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Figure 1:

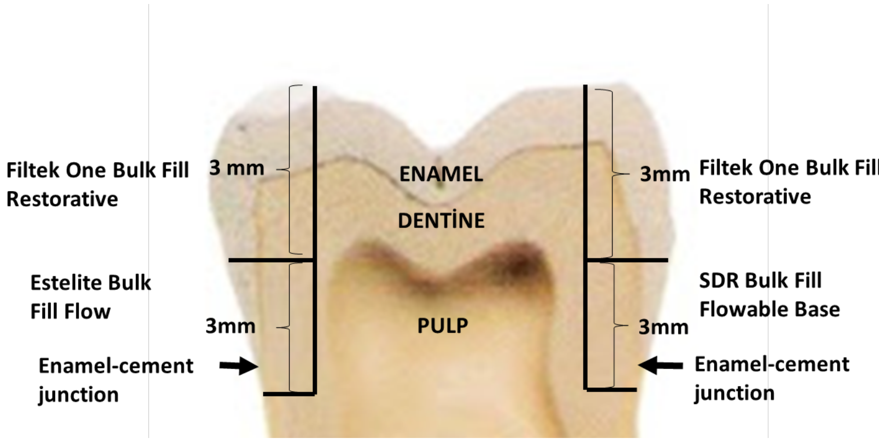
Schematıc Vıew Of The Restoratıon Procedure

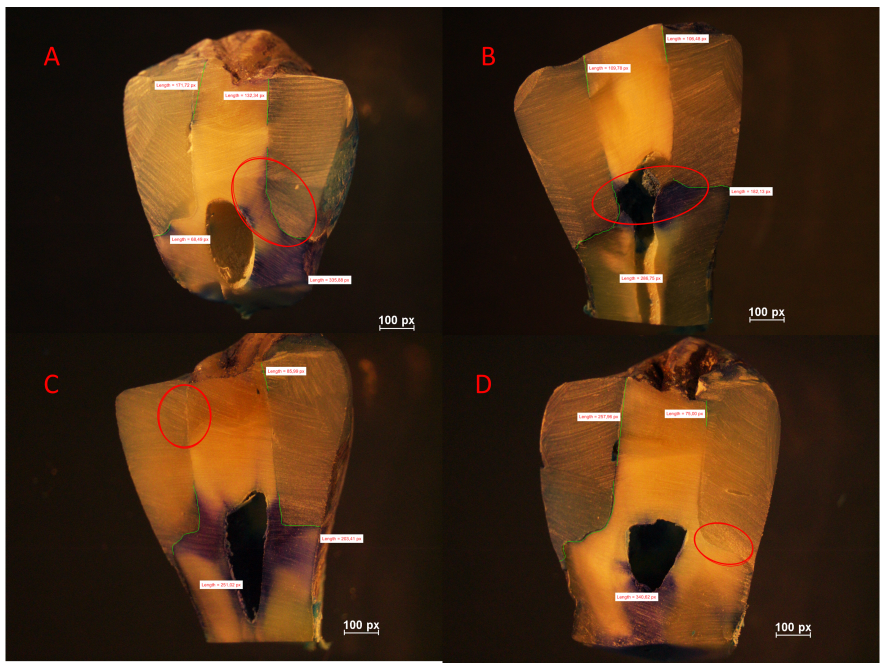
Figure 2:

A: Amounts of microleakage at 4 ° C in the lingual sectıon of the sample (Microleakage involving the axial wall is observed at the distal-gingival edge restored with SDR Posterior Bulk Fill Flowable Base)

B: Amounts of microleakage at room temperature in the lingual sectıon of the sample

C: Microleakage amounts at 39 ° C in the sample with lingual cross section (Microleakage is not observed in the mesial-occlusal margin restored with Filtek^{TM} One Bulk fill Restorative.)





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