Comparative study of resin composite class I restoration microleakage between bulk fill technique with and without sonic activation, and incremental technique

A D Kartikasari, D Indrawati and Kamizar*
Department of Conservative Dentistry, Faculty of Dentistry, Universitas Indonesia, Jakarta, Indonesia
*E-mail: kamizar_kz@yahoo.com

Abstract. A good marginal adaptation of a restoration can be measured by the absence of microleakage at the interface area. Resin composite undergo contraction during polymerization which may result in microleakage. The purpose of this study was to analyze the microleakage of class I cavity preparations that were filled with sonic-activated bulk-fill resin composite, bulk-fill resin composite without sonic activation, and composites that were filled incrementally. Standardized class I cavities were prepared in 27 extracted human upper premolars and randomly assigned to three groups. The first group was filled with sonic-activated bulk-fill resin composite; the second group was filled with bulk-fill resin composite without sonic activation; and the third group was filled incrementally. The specimens were subjected to: thermocycling; immersion in 1% methylene blue dye for 24 hours; sectioning longitudinally; evaluation of microleakage under a 12 x magnification stereomicroscope; and scoring on an ordinal scale (0–4). Statistical analysis was performed with a Kolmogorov-Smirnov test. There were no statistically significant differences among the three groups. Class I cavity preparations that were filled with resin composites incrementally have less microleakage compared to both sonic-activated bulk-fill and bulk-fill without sonic activation.

1. Introduction
The use of esthetic resin composite is increasing due to patients’ high demands for tooth-color restoration, the development of adhesive restoration material, and the use of resin composite for direct esthetic restoration becomes more widespread [1-3]. However, resin composite has some disadvantages. The procedure of resin composite restoration is technique-sensitive and time-consuming [4,5]. Another problem is related to its material adaptation. Restoration material adaptation relies on the contact tightness between the bond of the restoration material and the tooth surface [6]. Loss of contact between the tooth and the restoration material creates a leakage and becomes an entrance for bacteria and saliva. This condition causes post-operative sensitivity, pulp inflammation, discoloration, and secondary caries [7-9].

The success of composite resin restoration depends on various factors; one of them is the tightness on the composite-cavity interface. Composite resin will undergo volume shrinkage when polymerization occurs because the structural monomer will approach each other to bond. This will cause stress on the surface of adhesion of composite resin and the cavity wall. On the area which the polymerization contraction is bigger compared to the bond of the tooth structures and composite resin,
a gap will be formed causing adhesion failure and microleakage [10]. Various factors will influence the contraction stress of the composite resin restoration, for examples: cavity configuration factors (C-factor), materials, thermal expansion coefficient, modulus elasticity, higroscopic expansion, and polymerization contraction [8].

Incremental placement technique has widely known as a technique that is used to outgrow the polymerization contraction process that has high C-factor. This technique is used by placing the composite resin incrementally into the cavity with 2 mm maximum thickness for every increment. A prior study that by using this technique the contraction stress that happened on one increment could be compensated by the next increment so only the polymerization contraction from the last increment will destruct the bond [11]. Oblique incremental technique on this study was chosen because it could give lower contraction stress & microleakage compared to other incremental technique [12,13].

Microleakage could function as an entrance for bacteria or other molecules that can cause discoloration on restoration margin [14,15]. On microleakage studies, the resulting conclusion could be different because of the different protocols that were taken, irregular and complicated leakage pattern, and the area that was observed didn't show the whole leakage that happen [14]. The purpose of this study is to analyze the difference in microleakage levels of class I resin composite restoration using sonic-activated bulk-fill, bulk-fill without sonic-activation, and incremental techniques.

2. Materials and Methods
Twenty seven maxillary and mandibular first premolars that fitted the inclusion criteria were cleaned of soft tissue and calculus using a scaler, rinsed in flowing water, and placed in saline solution before treatment. Class I cavity preparation was carried out with a buccolingual width of 3 mm; a mesiodistal width of 3 mm; and a 3 mm depth using a cylindrical diamond burr with high speed and water cooling. The surface angle was not beveled. The procedure was performed by one operator. The cavity was etched for 15 seconds and then rinsed with water for 10 seconds. After this, the cavity was gently dried with air spray until moist. Next, adhesive was applied to the cavity using a microbrush, left for 10 seconds, then blown gently with air spray to evaporate the solvent and lightly cure for 10 seconds.

In group I, the resin composite was applied, at one time (bulk-fill), to the cavity using a special hand piece and then sonic-activated. The resin was light-cured for 20 seconds from the occlusal direction. In group II, the resin composite was bulk-filled into the cavity using a plastic filling instrument and light-cured for 20 second from the occlusal direction. For group III, the first layer of resin composite was applied incrementally with an oblique technique with a 2 mm depth using a plastic filling instrument then light-cured for 20 seconds from the occlusal direction. The next layer was applied to the occlusal surface and then light-cured for 20 seconds. After the restoration procedure was performed, the restoration surface was polished using enhance and then immersed in aquadest at 37 °C for 24 hours.

A thermocycling procedure was manually performed 250 times at 5 °C and 55 °C for 1 minute each with 15 second rests. After the thermocycling procedure, an apical section was cut 2 mm from the tip of the apex using a diamond disc with cooling water. The apical was patched with resin modified glass ionomer cement. All the tooth surfaces were coated with two layers of red nail polish except from 1 mm from the tooth’s restoration line angle. The nail polish was dried for 12 hours. The specimens were immersed in 1% blue methylene for 24 hours at 37 °C in an incubator. After the specimens were rinsed with water for 10 minute, they were dried and cut in the buccolingual direction into two pieces using a low speed diamond disc. From these two parts, one was chosen based on color penetration as seen with a stereomicroscope with 12 x enlargement. Statistical analysis was done using the non-parametric Kolmogorov-Smirnov (KS) test with significance value p < 0.05.

3. Results and Discussion

3.1 Results
This study evaluated microleakage on each of the tooth-restoration surface walls for twenty seven Class I restored teeth using a microscope with 12x magnification. The penetration depth of the 1%
methylene blue was measured and scored based on a scale proposed by Santosh et al., score 0 (no penetration); score 1 (penetration to 1/3 the depth of the cavity); score 2 (penetration >1/3 but <2/3 the depth of the cavity); score 3 (penetration >2/3 the depth of the cavity); and score 4 (penetration to the floor of the cavity and involvement of dentine tubules) [10].

The observations were conducted by two observers. The external and internal validity and reliability of each observer was tested by a Kappa test. In this study the result of the Kappa test was more than 80% that indicated good agreement between the two observers. After meeting the requirements, the analyzed microleakage from the three groups was tested using a chi-square test. However, the chi-square requirement of a 20% minimal expected value for each cell was not fulfilled, so the KS test was performed to analyze the three groups.

Table 1. Class I microleakage score distribution

| Composite resin group | Microleakage score | Total |
|-----------------------|--------------------|-------|
|                       | 0      | 1      | 2      | 3      | 4      |       |
| BFS                   | n   | %     | n   | %     | n   | %     | n   | %     |       |
| BF                    | 2   | 7.4   | 0   | 0.0   | 0   | 0.0   | 0   | 0.0   | 7 25.9 9 |
| INK                   | 2   | 7.4   | 0   | 0.0   | 1   | 3.7   | 2   | 7.4   | 4 14.8 9 |
| Total                 | 4   | 14.8  | 0   | 0.0   | 1   | 3.7   | 2   | 7.4   | 20 74.1 27 |

Explanation: n=amount of samples; BFS= sonic activated Bulk-fill composite resin; BF= Bulk-fill composite resin without sonic activation; INK= Incrementally placed composite resin.

The results (Table 1) show the distribution of the microleakage scores for the class I restoration wall for: sonic activated bulk-fill, without sonic activation of the bulk-fill, and incremental. From the 27 samples that were observed, four samples scored 0 (14.8%), one sample scored score 2 (3.7%), two samples scored 3 (7.4%), and 20 samples scored 4 (74.1%). For group I, bulk-fill composite resin sonic activated (BFS), two samples scored 0 (7.4%), seven samples scored 4 (25.9%), and no sample scored 2 or 3. For group II, bulk-fill composite resin without sonic activation (BF), nine samples scored 4 (33.3%). In group III, incremental composite resin (INK), two samples scored 0 (7.4%), one sample scored 2 (3.7%), two samples scored 3 (7.4%), and four samples scored 4 (14.8%). Comparing the percentages from each group, we found that in group I, BFS, two samples scored 0 (22.2%), seven samples scored 4 (77.8%), and no samples scored 2 or 3. In group II, (BF), nine samples scored 4 (100%). In group III, (INK), two samples scored 0 (22.2%), one sample scored 2 (11.1%), two samples scored 3 (22.2%), and four samples scored 4 (44.4%).

Table 2. Significance values for restoration class I wall microleakage for each group

| Composite resin group | p-value |
|-----------------------|---------|
| BFS vs BF             | 0.979   |
| BFS vs INK            | 0.699   |
| BF vs INK             | 0.124   |

Explanation: n = number of samples; BFS = Bulk-fill composite resin sonic-activated; BF = Bulk-fill composite resin without sonic-activation; INK = incremental composite resin. Significance value p < 0.005.

From the Kolmogorov-Smirnov tests, with a significance value, p < 0.005, that were performed for each group, we found that the microleakage proportion in the class I restoration wall between the BFS group was not significantly different to the BF group (p = 0.979). The significance value between the BFS and the INK groups was also not significantly different (p = 0.124). The microleakage
significance value, in the class I restoration wall in this test, can be seen in Table 2. Photos of examples of microleakage in the specimens from this study are shown in Figure 1.

![Figure 1. Microleakage in the Specimens. Microleakage: (A) score 0; (B) score 2; (C) score 3; (D) score 4](image)

3.2 Discussion
The success of composite resin restoration depends on multiple factors. One of these is the contact tightness between the composite resin surface and the tooth surface. The volume of the composite resin will shrink when polymerized because the monomers polymerize. As a result, stress is produced in the resin composite’s surface adhesion to the tooth surface. In the region where polymerization contraction stress is highest, the resin composite adhesion to the tooth surface can create a gap that causes adhesion failure and microleakage [14]. Some factors that influence the polymerization contraction stress of composite resins are the cavity configuration factor (C-factor), the material factor, the thermal expansion coefficient, the modulus of elasticity, hygroscopic expansion, and polymerization contraction [8]. Microleakage creates an entrance way for bacteria and other molecules that can cause restoration line discoloration [15,16]. The conclusions of microleakage studies vary: the microleakage pattern was complicated and irregular; the part that was observed did not present the overall condition [14].

The color penetration method is commonly used to assess microleakage. This method is performed by immersing the specimens in a color solution for different times and the observations then performed on the frontier of the restoration material and tooth. Colored-frontiers indicate microleakage. This assessment was performed by observing microleakage from blue methylene immersion for 24 hours before thermocycling, as in the studies of Santosh [10]. Blue methylene was used in this study because it has small molecules (0.5–0.7 mm). It can also can penetrate deeper than others dyes. Consequently, blue methylene can give false positive numbers and show microleakage levels that are higher than clinically seen [15]. In vitro microleakage assessments on extracted teeth using dye solutions and analyzed qualitatively were introduced by Roulet et al. Previous [17] assessed microleakage at the frontier of the composite resin restoration from cut extracted teeth using dye solution examined by a SEM. This method was used to evaluate and compare microleakage caused by composite resin polymerization contraction. There is no exact standard to perform the procedure for evaluating microleakage.

Thermocycling was undertaken to test the adhesion of the restoration after continuous high and low temperature exposure, as in the oral cavity situation [18]. Continuous changes of temperature causes the destruction of surface adhesion between the tooth surface and the restoration due to the different thermal coefficients and lead to microleakage. In this study, the thermocycling procedure was performed 250 x at 5 °C and 55 °C (±2 °C) for 1 minute and rested for 15 seconds each time. This condition occurs in the oral cavity and was replicated as a clinical condition.

In this study, the cavity was made to a depth of 3 mm. A Class I cavity is preferable to a Class V cavity, which has five C-Factors to avoid pulpal exposure [19]. Class I preparation has the highest C-factor ratio that can cause the highest polymerization stress. Polymerization stress contraction is
microleakage caused by composite resin restoration. Some factors involved with stress contraction are C-factors, extensive cavities, composite resin application technique, light intensity, position, and the composite material itself. A C-factor is the ratio of contacted walls to not-contacted walls between the composite resin and the cavity. The higher the value of the C-factor, the higher the polymerization stress contraction. The variables in this study were the composite resin application techniques: sonic-activated bulk-fill technique, not sonic-activated bulk-fill technique, and incremental technique. Bulk-fill composite applied with sonic activation technique can shorten the time of the procedure so it is advantageous for the clinician.

From this study, microleakage in the BFS and BF groups was found to be not significantly different statistically (Table 2). Therefore, the hypothesis that microleakage in composite resin in Class I cavities with activated-sonic bulk-fill techniques is less that not activated sonic bulk-fill techniques was rejected. This was possibly caused by the Class I cavity form that has the highest C-factors. The application technique did not reduce the C-factor. It caused contraction stress to be formed that affects the larger volume of the composite resin and the polymerization effect is reduced in deep cavities [20]. The BFS group had reduced composite elasticity, up to 87%, when sonic-activated. However, when composite resin elasticity returned to normal, polymerization stress contraction still occurred. The polymerization stress contraction, which occurs at that time, is greater than the resin bond and can cause microleakage. From the data gathered in this study, BFS is better than BF because the decrease in the sonic-activated composite resin viscosity creates lower polymerization stress contraction compared to BF. Until now, no literature has directly explained the effects of sonic-activation on composite resin. It was assumed that the use of sonic-activation for restoration application techniques decreased the shear force on the material particles that decreased the material viscoelasticity, to enable better flow [21-23]. Better flow ability can create better adaptation of the composite resin to the tooth surface. This condition assumed polymerization occurred when the gelation point had not yet been reached. At this time, composite resin molecules move actively due to the sonic-activation. If the composite resin's modulus of elasticity is low, due to reduced viscosity, the polymerization stress contraction can be decreased. However, this phenomenon is still questioned and needs further study. Microleakage can still occur, but only the cut part of the tooth is observed. This is the weakness of this study, similar to that proposed by Fabianelli et al. in a relevant study of microleakage [9]. Besides this, BF’s volumetric contraction is higher than BFS with the volume of BF filler less than BFS, according to manufacturer’s information. It also contributes to this condition. The less the volume of composite resin filler material, the higher is the volumetric contraction [8]. The higher the composite resin volumetric contraction, the higher is the chance of composite resin contraction away from the tooth surface during polymerization [24]. These possibilities indicate that BF creates higher microleakage.

Incremental application techniques are generally used for composite resin applications to reduce the polymerization contraction in conditions with high C-factors. The procedure is carried out by applying 2 mm of composite resin into the cavity. Deliperi [20] stated that with this technique, the stress contraction in one incremental layer can be compensated for by the next layer, so that polymerization contraction occurs in the last layer.

An oblique incremental technique was chosen for this current study due to the microleakage of other incremental techniques [11,12]. In this study, the results between the oblique incremental and bulk-fill techniques, for a Class I cavity with more than 2 mm depth with a high C-factor (C-factor = 5), are not significantly different. This is in line with some previous studies about composite resin application techniques and microleakage in high C-factor cavity forms. Santosh et al., in a study of class I cavity forms and Duarte et al. in class V cavity forms that have 5 C-factors, reported that there was no significant difference between incremental and bulk-fill application techniques for microleakage [10,23]. Contrary to this finding, Yamazaki et al. suggested the use of incremental techniques, because of their lower microleakage compared to bulk-fill [25]. In studies of cavity forms with lower C-factors there was a shown a significant difference. Lopes et al. and Nadig et al., in their studies of class II cavity forms (C-factor = 2), reported that microleakage from incremental techniques
is lower than bulk-fill techniques [11,22]. Idris et al. and Poskus et al., in their studies on class II cavity forms (C-factor = 2), also reported that microleakage from incremental techniques is lower than bulk-fill techniques, but statistically it was no significant [12,13]. A possible cause of the discrepancies between the two studies is the lighting direction: from the facial or the lingual. It can be concluded that C-factors have an important role in composite resin application techniques. In cavities with higher C-factors, it is difficult to overcome microleakage even though the application technique being used is incremental.

In this study, microleakage compared between BFS and INK, or BF and INK, are not significantly different (see Table 2). All groups show microleakage. Accordingly, the hypothesis that composite resin restoration of class I cavity forms using sonic-activated bulk-fill techniques has lower microleakage than incremental techniques is rejected. Additionally, the hypothesis that composite resin restorations of class I cavity forms using bulk-fill techniques without sonic-activation has higher microleakage than incremental techniques is also rejected. Composite based resin material that losses its density with time can cause microleakage. Davidson et al. stated that polymerization contraction is responsible for composite-tooth gap formation. This study found the gap varies by 1.67% to 5.68% for total volume of restoration [15]. As well as this, new gaps will form while the restoration is exposed to thermal stress and mechanical wear. Loguercio et al., found that 24 hours after composite resin restoration, gaps 12.4–31.3 µm wide, were formed. This study also stated that these gaps will widen with exposure to others clinical variable such as thermal stress and loading [26]. Santosh et al., in their study testing composite resin microleakage in class 1 cavity forms, using tooth dye immersion and thermocycling, stated that both processes can cause artificial aging and a high risk of microleakage [10]. In a study about microleakage from bulk-fill sonic-activated composite from a resin manufacture's portfolio, no difference in restoration-tooth tightness for class II restoration was observed using SEM on sonic-activated bulk-fill composites, bulk-fill without sonic-activation, and incremental [27]. However, in this study, from the percentages, the INK group showed lower microleakage than the BFS and BF groups (Table 1). This is possible because the INK group had less C-factor so that stress contraction occurred less. Bulk-fill techniques for BFS and BF have higher stresses due to the greater composite volume to be polymerized [24]. As well as this, the level of polymerization effectiveness in the floor of cavity in bulk-fill technique is reduced [28]. Loguercio et al. reported that the incremental technique is proven to elevate bond strength because the incremental technique gives maximal and uniform polymerization in every incremental layer [26]. Without paying attention to C-factors, some studies show that incremental techniques have better significant outcomes than bulk-fill techniques [9,12,29,30]. An in vivo study by Lopes et al. compared gap formation in oblique incremental techniques to bulk-fill in class II restoration. They showed that oblique incremental techniques give better result [11]. Poskus et al. also showed that bulk-fill techniques create greater microleakage in cervical walls than incremental techniques [12]. A study of microleakage with loading applications reported that composite resin bulk-fill techniques had significantly greater microleakage than incremental techniques [25]. This is also supported by an in vitro study that compared restoration frontier microleakage in class II restorations with four different application techniques. In this study, they concluded that among the three incremental application techniques and one bulk-fill technique, the incremental techniques have significantly less microleakage than bulk-fill techniques [22]. However, incremental techniques are time consuming and do not solve microleakage problems for composite resin restoration. It is shown in this study that the outcomes of incremental application and bulk-fill have the same color penetration. In the incremental technique, contraction stress still occurs in last layer. Deliperi et al. also stated this for alternative ways of posterior tooth composite resin restoration [20]. Additionally, volume reduction compensation in the incremental technique is still questioned [31]. As in previous studies, the results of this study also question the effectiveness of incremental techniques to overcome polymerization stress contraction that affects microleakage [13,31]. Gallo et al., also found significant differences between incremental techniques and bulk-fill techniques for class II restorations [29]. This is also supported by Idris et al., in a microleakage study.
of class II restoration. Santosh et al., observed microleakage in class I cavities and reported no significant differences between bulk-fill and incremental composite resin technique applications [10, 13]. A previous study by Reis [30], also reported that adding elastic material can decrease stress, due to its lower modulus of elasticity, and prevents destruction of bonding created by adhesive resin while polymerization shrinkage occurs, even though it is proven that it does not increase bonding strength. Similarly, Duarte et al. stated that adding elastic material, as a transition layer between composite resin and teeth, compensates the polymerization stress contraction, and incremental techniques are enough to decrease microleakage [23]. It is suggested that further studies, to evaluate the effect of various composite resin application techniques on microleakage in class I restorations, should use three dimensional observations.

4. Conclusion
It can be concluded from this study that incremental application techniques have lower microleakage than bulk-fill with sonic-activation and bulk-fill without sonic-activation techniques for class I composite resin preparation.

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