

Influence of flowable composite lining on microleakage at the gingival dentin margin

Jung Min Lee, Young Kyung Kim, Jeong-won Park

Department of Conservative Dentistry, School of Dentistry, Kyungpook National University

국문초록

유동성 레진이 치은 상아질 변연 누출에 미치는 영향

이정민 · 김영경 · 박정원

경북대학교 치과대학 치의학과 보존학교실

2급 복합레진 수복 와동의 치은 변연이 상아질 상에 있을 때 유동성 레진 이장의 유무와 두께가 미세누출에 미치는 영향을 알아보기 위해 본 실험을 시행하였다.

60개의 발거된 대구치의 근, 원심면에 각각 협설측 3mm, 치은벽 깊이 1mm의 2급 와동을 형성하고 치은 변연은 법랑-백아 경계에서 약 1mm 하방에 위치 시켰다. 모든 와동을 32% 인산으로 15초 처리 및 30초 수세 후 Prime & Bond® NT 상아질 접착제를 적용하였고, Tetric Ceram(TC), Tetric Flow(TF)를 이용하여 다음의 6가지 군으로 나누어 수복하였다. (1) TC로 수평 적층 충전, (2) TC로 수직 적층 충전, (3) 0.5-1mm 두께로 TF 이장 후 TC로 수평적층 충전, (4) 0.5-1mm 두께로 TF 이장 후 TC로 수직 적층 충전, (5) 2-3mm 두께로 TF 이장 후 TC로 수평적층 충전, (6) 2-3mm 두께로 TF 이장 후 TC로 수직 적층 충전. 충전된 시편을 37℃, 100% humidity에서 24시간 보관하고 5℃와 55℃에서 500회의 열순환을 실시하여 치은 변연의 0.5mm 외부에 nail varnish를 도포 하여 2% methylene blue 용액에 12시간 침잠시켰다. 시편을 아크릴릭 레진에 매몰하여 수복물의 중앙에서 종절단 한 후 입체현미경하에서 색소의 침투도를 관찰하여 다음과 같은 결과를 얻었다.

유동성 레진의 이장을 시행한 군과 하지 않은 군간에 미세누출은 유의차를 보이지 않았다($p>0.05$). 유동성 레진의 두께에 따른 미세누출의 차이는 나타나지 않았다($p>0.05$). 경사면 충전법을 시행한 군에서는 유동성 레진을 이장한 군들이 이장하지 않은 군보다 유의하게 많은 누출을 보였다($p<0.05$). 수평적층 충전법을 시행한 군에서는 유동성 레진 이장이 미세누출에 유의한 차이를 보이지 않았다($p>0.05$).

Key words : Flowable composite resin, Class II resin restoration, Microleakage

I. Introduction

Since the 1980s more and more clinicians have been choosing composite restoration materials in lieu of amalgam for posterior teeth fillings. This is due to the increase in patients' demand for and clinicians' interest in posterior esthetic restoration. Also, there is also a growing concern about the possible risks of mercury toxicity associated with the use of amalgam restorations and the

improvement of resin composites due to advanced technology.

Mechanical properties of composite resin have been improved last few decades, but resin shrinkage due to polymerization has been reported as one of the factors directly responsible for marginal leakage at the tooth-restoration interface. In vitro measurements of the polymerization shrinkage of resin composites range from 0.2 % to 2 % linear shrinkage¹⁾ and from 2.6 % to 7.1 % volumetric

shrinkage^{2,3)}. Particularly in the deep part of proximal box of Class II cavities, polymerization shrinkage can result in a lack of adaption to the cavity wall, microleakage, marginal discoloration, postoperative hypersensitivity, bacterial invasion, and, eventually, increased susceptibility to caries, and replacement of composite restorations⁴⁻⁶⁾.

For the compensation of polymerization shrinkage, several restorative techniques have been suggested to minimize the development of stresses at the margins and to improve the marginal sealing of a composite restoration: incremental filling⁷⁻⁹⁾; three-sided light curing^{10,11)}; transparent cones adapted to the light guide¹²⁾; ceramic inserts¹³⁾; directed-shrinkage¹⁴⁾; resin-modified glass ionomer as the gingival increment¹⁵⁾; and flowable composite resin-lining¹⁶⁻¹⁸⁾.

Flowable composite has low elastic modulus and relieves the contraction stress during polymerization^{17,19,20-23)}. A few researches have reported on microleakage in Class II composite restoration using flowable composite lining to seal the gingival margin at the dentin. In some in vitro studies, it has been reported that the use of flowable composite as a liner in Class II condensable composite restoration reduced microleakage^{17,18,24)}.

On the other hand, some authors reported a flowable composite lining in a Class II resin filling could effectively reduce voids at the interface, but would not necessarily improve marginal sealing²⁵⁾ and there was a trend, although not a statistically significant one, for more microleakage of the flowable composite lining groups at both the enamel and cementum margins²⁶⁾. Therefore, not only low modulus of elasticity but also the high polymerization shrinkage of flowable composite needs to be considered when investigating the influence of flowable composite on marginal sealing.

Because of these conflicting factors – low elastic modulus and high polymerization shrinkage – the thickness of flowable composite lining also needs to be considered. A thin layer produces very little shrinkage stress because of the favorable configuration, and, according to the concept of an “elastic cavity wall”^{19,20,27)}, for any given modulus, a

thicker layer will absorb more stress²²⁾. However, there is no study on the effect of varying thicknesses of flowable composite lining and the use of flowable composite lining is controversial.

The purpose of this study was to investigate the influence of flowable composite lining and its thickness on microleakage at the gingival dentin margin when using different insertion techniques of overlying composite resin in Class II composite restoration.

II. Materials and Methods

Materials

Sixty extracted human molars without decay or previous restoration were chosen. The teeth were scaled with periodontal curette and cleaned with tap water. They were stored in physiological saline at 4°C until use.

Composite resin, Tetric® Ceram A2 (Ivoclar Vivadent, Schaan, Liechtenstein) and its compatible flowable composite resin, Tetric® Flow A2 (Ivoclar Vivadent, Schaan, Liechtenstein) were selected as experimental materials. The dental adhesive system, Prime & Bond® NT (Dentsply DeTrey GmbH, Konstanz, Germany) was applied.

Specimens were irradiated by a visible light-curing unit (Spectrum™ 800, Dentsply DeTrey GmbH, Konstanz, Germany) of 700 mW/cm² light intensity.

Preparation of the specimens

Class II box-only cavities without retention lock were prepared on the mesial and distal surfaces of each tooth using a diamond bur in a high-speed handpiece with water spray. These slot preparations were separated with no occlusal connection. The buccolingual width was 3 mm and the gingival wall depth was 1 mm. The cavosurface margin at the gingival floor of all cavities was apically placed approximately 1 mm from the cemento-enamel junction. These distances and depths were measured with a periodontal probe. The internal angles were rounded and the cavosurface margins

were sharp and nonbeveled. Buccal and lingual walls of the preparations were approximately parallel and connected to the gingival wall with rounded line angles. A new bur was used for every five preparations to ensure cutting efficacy. One operator prepared the standard cavities.

The cavities were randomly divided into six groups of twenty cavities. A Tofflemire matrix retainer and a soft metal band were placed on each tooth. The matrix was tightened and held by finger pressure against the gingival margin of the cavity so the preparations would not be filled above the gingival margin. All specimen cavities were acid etched for 15 seconds using 32 % phosphoric acid gel (UNI-ETCH®, Bisco, Inc., Schaumburg, IL, U.S.A.) and the teeth were then washed thoroughly for 30 seconds and gently air dried to remove excess water without desiccation. A dentin bonding agent, Prime & Bond® NT (Dentsply DeTrey GmbH, Konstanz, Germany) was applied according to the manufacturer's instructions and cured for 20 seconds from the occlusal aspect using a visible curing light (Spectrum™ 800, Dentsply DeTrey GmbH, Konstanz, Germany).

Each cavity was restored according to the filling technique shown in Table 1.

The flowable composite lining was light cured for 40 seconds from the occlusal aspect. Using the horizontal incremental insertion technique, each cavity was filled with a maximum thickness of 2 mm per increment and each increment was light cured for 40 seconds from the occlusal aspect.

Using the oblique incremental insertion technique, composite resin increments were inserted in a slanted direction and individually light cured for 40 seconds from the occlusal aspect.

The matrix was removed after restoration was completed. A #15 surgical blade was used to remove any excess material, especially at the gingival margin. Required finishing was minimal. Gross overhangs were removed with a scalpel blade, cutting from the restoration towards the cavity margin, to avoid creating marginal gaps that might compromise the results.

All restored teeth were stored at 37°C and 100% humidity for 24 hours. They were then thermocycled 500 times with a 30 second dwell time in a water bath between 5°C and 55°C.

Dye Leakage Test

The root apex was sealed with wax, and the entire tooth was coated two times with nail varnish, apart from 1-mm-wide zone adjacent to the gingival margins of the composite restoration. When the nail varnish was dry, the specimens were immersed in a 2 % methylene blue solution for 12 hours. Subsequent to this, the teeth were rinsed with tap water for 12 hours.

Evaluation of Microleakage

After the teeth were embedded in auto-polymerizing acrylic resin (Orthodontic Resin, Dentsply/Detray, Konstanz, Germany), they were sectioned

Table 1. Filling techniques investigated in this study

Group	Flowable composite lining and its thickness	Incremental insertion technique of overlying composite resin
1	Not used	horizontal
2	Not used	oblique
3	0.5 - 1 mm	horizontal
4	0.5 - 1 mm	oblique
5	2 - 3 mm	horizontal
6	2 - 3 mm	oblique

longitudinally, in a mesiodistal direction coincident with the center of the restorations using a slowly rotating diamond saw (Isomet™, Buehler Co., Lake Bluff, IL, U.S.A.). The sectioning resulted in two approximately equal parts, which were both analyzed for microleakage. The sections were coded and analyzed under a stereomicroscope (SZ-PT 40, Olympus Optical Co., Ltd., Tokyo, Japan) at X 25 magnification. For the purpose of dye penetration analysis, only the gingival floor of the tooth/restoration interface was considered. The following leakage scores were attributed, according to the severity of dye penetration: 0 = no evidence of dye penetration; 1 = dye penetration to less than half the cavity depth; 2 = dye penetration to the full cavity depth; 3 = dye penetration to the axial wall and beyond.

Table 2. Frequency of dye penetration scores

Groups	Score				Total
	0	1	2	3	
1	0	3	8	9	20
2	0	10	7	3	20
3	0	8	2	10	20
4	0	7	3	10	20
5	0	5	4	11	20
6	0	6	2	12	20
Total	0	39	26	55	120

No significant difference between groups ($p > 0.05$).

Table 3. Frequency of dye penetration scores for oblique incremental fillings

Groups	Score				Total
	0	1	2	3	
2	0	10	7	3	20
4	0	7	3	10	20
6	0	6	2	12	20
Total	0	23	12	25	60

Groups connected by a line are statistically equivalent.

Any discrepancies between the two main examiners' findings were reevaluated, and when necessary, a third examiner decided the score.

Statistical Analysis

Differences between the frequency of dye leakage scores in the experimental groups were subjected to statistical analysis with chi-square test and Fisher's exact test. Corresponding p -values were considered significant at values less than 0.05.

III. Results

Result of dye penetration scores in each group is presented in Table 2.

Flowable composite lining groups did not show significantly less microleakage than non-lining groups ($p > 0.05$).

When using oblique incremental fillings, flowable composite lining groups showed statistically more leakage than non-lining group ($p < 0.05$), but there was no significant difference between the two flowable composite lining groups ($p > 0.05$) (Table 3). In horizontal incremental fillings, flowable composite lining and non-lining groups did not show any significant difference in microleakage ($p > 0.05$) (Table 4).

Thickness of flowable composite lining did not induce any significant difference in the depth of dye penetration ($p > 0.05$).

Table 4. Frequency of dye penetration scores for horizontal incremental fillings

Groups	Score				Total
	0	1	2	3	
1	0	3	8	9	20
3	0	8	2	10	20
5	0	5	4	11	20
Total	0	16	14	30	60

Groups connected by a line are statistically equivalent.

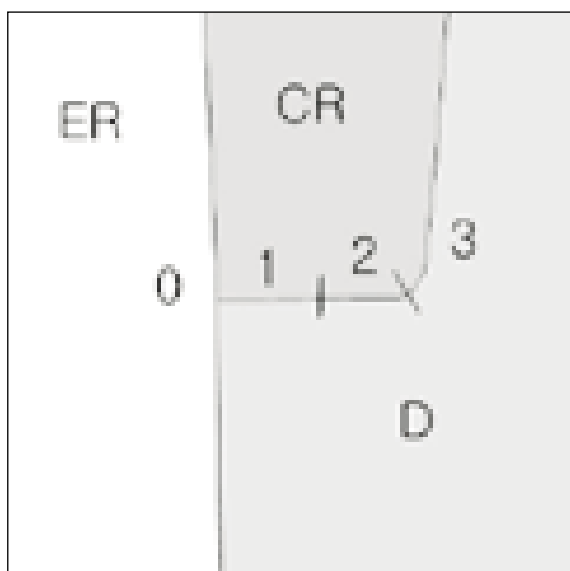


Fig. 1. Dye leakage test score. 0=no leakage, 1; leakage within half of the gingival wall, 2; leakage within the gingival wall, 3; leakage pass the gingival wall to the axial

(D=dentin, CR=composite resin, ER=embedding resin)

IV. Discussion

A major disadvantage of posterior composite restorations is polymerization shrinkage. Polymerization shrinkage of posterior composite restorations may induce mechanical stresses on the tooth structure via the bond to enamel and dentin. The insertion of bonded resin composites in cavity preparations leads to a competition between polymerization contraction forces and the strength of bonds to tooth structure. If the bond between the composite and the tooth structure is less than the force of polymerization shrinkage, a marginal failure and subsequent microleakage will occur^{28,29}. The marginal seal can generally be preserved around cavity preparations when cavosurface margins are restricted to enamel. This is due to the strong adhesion achieved with this inorganic tissue³⁰ and because the contraction force during setting is counteracted by bonding to the beveled and etched enamel. However, in Class II cavities where the cervical margin is located on the root dentin apical to the cemento-enamel

junction, contraction forces may exceed the adhesive strength of the bonding agents to dentin³¹, and consequently a gap may form at the interface³².

Many techniques have been suggested to improve the marginal sealing of Class II composite restorations. The magnitude of polymerization stress depends on the amount of polymerization shrinkage and elastic modulus(Hooke's law). And, for a given degree of polymerization shrinkage, less elastic modulus cause less polymerization stress. Some researchers have proposed the use of low-modulus lining material, such as flowable composite. It has been reported that the use of flowable composite liner in Class II condensable composite resin restoration reduced microleakage^{17,18,24}. But flowable composite developed in response to requests for special handling properties rather than for any clinical performance criteria has not only low modulus of elasticity but also high polymerization shrinkage because of low filler content.

This study was performed to investigate the influence of flowable composite lining and its thickness on microleakage at the gingival dentin margin when using different insertion techniques of overlying composite resin in Class II composite restoration.

Some manufacturers suggest use of flowable composite as liners in areas of difficult access, such as irregular internal surfaces and proximal boxes of Class II preparations. The idea behind the use of flowable composite is to take advantage of its flow capacity in filling all parts of the box due to low viscosity, facilitated by the rounded line angles^{33,34,35}. Another expected advantage is its lower modulus of elasticity in comparison with other hybrid composites^{33,36}. This characteristic could contribute to the alleviation of contraction stresses during polymerization. While flowable composite liners may provide better adaptation, they may also act as a flexible intermediate layer, which helps relieve stresses during polymerization shrinkage of the restorative resin^{18,19,21,23}. Leevailoj et al.¹⁷ reported that flowable composite liners with lower elastic modulus and less viscosity

helped reduce microleakage at gingival enamel margins of all Class II condensable resin restorations.

However, some studies reported that the use of flowable composite did not reduce the microleakage. It is coincident with the result of this study. Chuang et al.²⁵⁾ reported a flowable composite lining in Class II composite restoration with all enamel margins could effectively reduce voids in the interface and the total number of voids in the restoration, but would not necessarily improve marginal sealing. The differences in the present study are the location of gingival margin and leakage being much more than in their study. Beznos²⁶⁾ evaluated microleakage at the cervical margins of Class II composite resin restorations which employed different techniques. All techniques worked well for enamel, with almost no leakage. However, on cementum, all techniques demonstrated moderate to severe leakage. Besides this, similar to the present study, there was a tendency for more microleakage on the flowable composite lining group in both enamel and cementum margins. In the study of Leevailoj et al.¹⁷⁾, flowable composite lining did not help reduce microleakage at the gingival margin in microhybrid composite resin group or control group.

A few things may account for this result. Flowable composites are reported to shrink more than traditional composites because they have less filler content (60–70% by weight and 46–70% by volume) and a greater proportion of resin matrix than hybrid resins³⁷⁾. The greater proportion of resin matrix in flowable composite resins may contribute to their greater shrinkage during polymerization. According to the 3M Technical Product Profile, Tetric® Flow has a volumetric shrinkage of about 4 %, and it is almost the double of conventional microhybrid composite Z-250. Alomari et al.³⁸⁾ showed that posterior composite restorations cause stress on tooth structure, and this stress, in conjunction with strong bonding between the restoration and the cavity walls, leads to deflection of the cusps. The use of low elastic modulus liners reduced cusp deflection at five minutes after curing, but resin-modified glass

ionomer was more effective in that regard than the flowable composite. They explained that this could be due to other variables such as the flow, polymerization shrinkage and degree of adhesive bonding of the materials, and that high polymerization shrinkage could explain why the flowable composite, although it had low elastic modulus, was not as effective as the resin-modified glass ionomer in reducing cusp deflection.

Another explanation could be the utilization of occlusal irradiation. The layering technique of composite resin and the use of clear matrix and reflective wedges were advocated as an efficient method to eliminate polymerization stress^{7,39)}. They suggested that this technique allows light curing through the wedge to produce shrinkage toward the gingival margin. However, the ability of reflective wedges to cure resin composite has been contested and the ability of clear wedges to ensure the polymerization of the composites is limited⁴⁰⁾. Also, Neiva et al.¹²⁾ has found that the incremental filling technique using a clear matrix and reflective wedges demonstrated the worst results in Class II resin restoration when the cervical wall was in cementum. The proximal contact is also more difficult to obtain using clear matrix⁴¹⁾. Therefore, in this study a metal matrix and a wooden wedge were used. It was argued that occlusal irradiation tends to pull out the composite from the margins, as it shrinks toward the light source^{11,39,42)}. Despite the results of recent papers contesting it⁴³⁾, polymerization of the resin composite towards the light source remains the most accepted theory⁴⁴⁾ and this type of polymerization has problems, such as the distance of the increment to the light, leading to subpolymerization of the cervical increment, mainly at its inner part^{45,46)}, resulting in poor adhesion and impaired physical properties due to less than ideal conversion of the resin monomers. This situation is even worse in deep cavities, such as those with margins apical to the cemento-enamel junction. And the gingival wall located in cementum of root dentin represents a longer distance to the light source which could increase polymerization stress, leading to greater leakage values. Kinomoto and

Torii³²⁾ found a polymerization stress of 8-23 MPa in lateral walls and 11-23 MPa in gingival wall. Since these values may be higher than the adhesion obtained to cementum margins in deep cavities, gaps could occur resulting in microleakage.

Thin and thick flowable linings were applied and compared in the present study. A thin liner was placed as thin as possible so that only a layer of 0.5 to 1 mm of the material was applied, while thick liner was finished near the contact point (2 to 3 mm) because the wear rate of flowable composites is higher than that of resin composites and flowable composites should be used only at contact-free areas^{33,47)}. Recently, the concept of an "elastic cavity wall" has also gained attention^{19,20,27)}. The concept is that shrinkage stress of subsequently applied resin composite can be absorbed by a relatively elastic initial layer, thereby reducing the stress at the restorative-tooth interface. Stress absorption is determined by thickness and modulus, and, for any given modulus, a thicker layer will absorb more stress²²⁾. Nevertheless, in the present study, thickness of flowable resin liner did not show any significant difference in microleakage.

In an effort to reduce polymerization shrinkage at the tooth/restoration interface, many restorative techniques have been suggested. One of the most widely used techniques is layering^{7,8,9,48)}. Neiva et al.¹²⁾ reported that there were no significant differences in leakage on enamel margins, and on cementum margins, oblique and horizontal incremental insertion and polymerization techniques using the collimator cone exhibited the least leakage and that, similar to the present study, oblique incremental insertion showed less leakage than horizontal incremental insertion, but there were no significant differences. In this study, there were no significant differences on dye penetration between horizontal and oblique incremental fillings in flowable composite lining groups, but in groups without flowable composite lining, oblique incremental filling showed less leakage than horizontal incremental filling. This result likely indicates that the first flowable composite layers have more effect on microleakage of

the restoration than incremental techniques of overlying composite resin in cases with flowable composite lining.

In summary, flowable composite lining groups did not show significantly less microleakage than non-lining groups, and in oblique incremental fillings, flowable composite lining groups showed statistically more leakage than non-lining groups. In horizontal incremental fillings, flowable composite lining did not cause any significant difference in leakage. Thickness of flowable composite liner did not show any significant difference in the depth of dye penetration. Within the limits of this study, it can be concluded that none of the tested techniques eliminated microleakage when the cervical margins were located in dentin and flowable composite lining seems to have no positive effect on microleakage at gingival dentin margin in Class II composite restoration. Therefore, although some authors and manufacturers are recommending the utilization of a flowable composite as the first increment in a Class II restorations, it should be noted that there were no statistical differences among the techniques employed, but there was a tendency for poorer results with the flowable technique. Further studies should be carried to evaluate the effect of flowable composite lining on the marginal leakage of composite restorations.

V. Conclusion

The purpose of this study was to investigate the influence of flowable composite lining and its thickness on microleakage at gingival dentin margin under different insertion techniques of overlying composite resin in Class II composite restoration.

Sixty extracted human molars were prepared as box-only Class II form on the mesial and distal surfaces with high-speed diamond bur. The buccolingual width was 3 mm and the gingival wall depth was 1 mm. The gingival margin was extended to approximately 1 mm below the CEJ. The prepared cavities were randomly assigned to six groups of twenty cavities. Tetric® Ceram(TC)

(Ivoclar Vivadent, Schaan, Liechtenstein) and Tetric® Flow(TF)(Ivoclar Vivadent, Schaan, Liechtenstein) were selected as experimental materials and the cavities were restored according to the following technique: (1) horizontal incremental TC filling, (2) oblique incremental TC filling, (3) horizontal incremental TC filling with TF liner (0.5 to 1 mm thick), (4) oblique incremental TC filling with TF liner, (5) horizontal incremental TC filling with TF liner(2 to 3 mm thick) or (6) oblique incremental TC filling with TF liner. Specimens were stored at 37°C and 100% humidity for 24 hours and thermocycled 500 times (5°C and 55°C), then immersed in a 2 % methylene blue solution for 12 hours. After sectioning mesio-distally through the restorations using an Isomet™ (Buehler Co., Lake Bluff, IL, U.S.A.), the degree of dye penetration was scored under a stereomicroscope (SZ-PT 40, Olympus Optical Co., Ltd., Tokyo, Japan) at X 25 magnification. The data were analysed statistically using chi-square test and Fisher's exact test.

The results were as follows:

- Flowable composite lining groups did not show significantly less microleakage than non-lining groups($p>0.05$).
- Thickness of flowable composite liner did not show any significant difference in the depth of dye penetration($p>0.05$).
- In oblique incremental fillings, flowable composite lining groups showed statistically more leakage than non-lining groups($p<0.05$), but there was no significant difference between the other flowable composite lining groups ($p>0.05$).
- In horizontal incremental fillings, flowable composite lining did not show any significant difference in leakage($p>0.05$).

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