# The Effect of Surface Sealing on the Microleakage of Class V Composite Resin Restorations

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## Abstract

This in vitro study was performed to assess the effect of surface sealing on the microleakage of class V composite resin restorations that underwent several aging treatments.

Class V cavities were prepared on the buccal surface of 100 sound extracted premolars and restored with a hybrid light-cured composite resin according to the manufacturer's instructions. They were randomly divided into two groups consisting of 50 samples: group I, without surface sealing, and group II, in which margins were etched and surface sealant was applied. After thermocycling, each group was divided into five subgroups, respectively, to represent the five aging treatments: group A = no further treatment (only thermocycling), B = toothbrushing, C = load cycling, D = toothbrushing followed by load cycling, and E = aging treatment in deionized water for six months. Microleakage was assessed by examining the penetration of 2% methylene blue dye.

The following results were obtained:

1. At occlusal and cervical margins in groups without surface sealing, there was no significant difference in microleakage after the several aging treatments ($p>0.05$).
2. The occlusal margins of groups with surface sealing showed no significant differences after the several aging treatments ($p>0.05$).
3. In the cervical margins of groups with surface sealing, microleakage significantly increased after load cycling or aging in deionized water for six months ($p<0.05$).
4. The no-further-treatment group and the toothbrushing group with surface sealing showed less microleakage than the corresponding groups without surface sealing ($p<0.05$).
5. The surface-sealed groups with load cycling or aging in deionized water showed no significant difference in microleakage to the corresponding groups without surface sealing ($p>0.05$).

In conclusion, the results of this study suggest that the surface sealant infiltrating through the gap of the cervical margin exerted a positive effect on microleakage at the initial stage, but the effect was not sufficient to overcome the stress generated by the cuspal flexure during occlusal loading and water absorption.

**Key words** : Surface sealing, Microleakage, Toothbrushing, Load cycling, Water absorption

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## Ⅰ. INTRODUCTION

The perfect adaptation of a restoration to the cavity margins is the key to the success of restorative treatments. Microleakage and subsequent penetration of bacteria, oral fluids, ions, and molecules can cause postoperative pain, discoloration, and pulp irritation, and can initiate recurrent caries[1-3].

Composite resins are used widely for esthetic restorations of class V lesions. Polymerization shrinkage, the main disadvantage of composite resins, can result in microgap formation and subsequent microleakage in the marginal areas[4]. In particular, bonding composite resin to dentin or cementum poses a significant clinical problem for dentists[5-7]. One clinical technique recommended for improving marginal integrity is 'surface sealing', the application of surface sealants on the composite resin restorations[8-19]. These resins, which are called surface sealants or surface-penetrating sealants, are expected to penetrate into the interface by capillary action and reduce microleakage[10,18-21].

The use of unfilled resins as glazes for covering composite resins was first suggested to improve the optical qualities of composite resins in anterior restoration[22]. Afterwards, it was reported that the application of a low-viscosity surface-penetrating sealant offers a viable approach for improving the wear resistance of posterior composite resins as well as reducing microleakage[23-24].

However, over a prolonged period, additional physical, mechanical and thermal stresses in the moist mouth due to temperature fluctuations, mastication, toothbrushing, and water absorption are applied to the restorative material as well as to the surface sealant. Thus, it was thought to be important to study the potential effects of these factors on microleakage.

There has been no long-term evaluation of whether the surface sealing has a positive effect on microleakage given the stresses generated in the oral environment. Therefore, the purpose of this study was to evaluate the effects of surface sealing on the microleakage of class V composite resin restorations after several aging treatments.

## Ⅱ. MATERIALS AND METHODS

One hundred caries-free human premolars were used for the study. After the teeth were cleaned of soft tissue and debris with a hand scaler, 100 class V cavities with the occlusal margins in enamel and cervical margins in dentin and cementum were made with a No. 330 carbide bur in a high-speed handpiece with air-water spray. The cavity outline had a mesiodistal width of 4 mm and an occlusogingival height of 3 mm. The depth of the cavity was approximately 2 mm.

Immediately after preparation, the cavities were etched with a 37% phosphoric acid etchant for 15 seconds, rinsed for 15 seconds, and then gently air-dried for two seconds. Scotchbond multi-purpose primer (3M Dental Products, U.S.A.) was applied over the enamel and dentin surfaces with a light scrubbing motion and gently air-thinned for five seconds. Scotchbond multi-purpose adhesive (3M Dental Products, U.S.A.) was applied and light cured for 10 seconds with a visible light-curing unit with an output of 400 mW/㎠ (XL 3000, 3M Dental Products, U.S.A.).

A hybrid light-activated composite resin (Filtek Z250, 3M Dental Products, U.S.A.) was inserted with appropriate instruments using the incremental filling technique: each increment, about 1 mm thick, was light cured for 20 seconds. The restorations were then polished with Sof-Lex abrasive disks (3M Dental Products, U.S.A.). Specimens were randomly divided into two groups of 50 teeth each. One group did not receive surface sealing (group I). In the other group, restorations were treated in accordance with the procedures for the surface sealing technique (group II): The surface and adjacent enamel and dentin-cementum margins (2 mm beyond the tooth-restoration interface) were etched with a 37% phosphoric acid for 15 seconds and rinsed for 15 seconds. Excess water was removed with a gentle air stream, and a uniform layer of the specific surface-penetrating sealant (Fortify, Bisco Inc., U.S.A.) was applied over the etched area. The material was applied with a disposable microbrush in a light scrubbing motion and light cured for 20 seconds.

All of the specimens were stored for seven days in deionized water at 37℃, and were submitted to a thermocycling regimen of 500 cycles between 5℃ and 55℃ water baths. Dwell time was 30 seconds.

After thermocycling, each group was divided into five subgroups of 10 teeth each to represent the five aging treatments: group A = no further treatment (only thermocycling), B = toothbrushing, C = load cycling, D = toothbrushing followed by load cycling, and E = aging treatment in deionized water for six months (Table 1).

Load cycling was performed by chewing strokes in an MTS system(858 Mini Bionix II Test System, MTS Systems Corporation, U.S.A.). The loading cycle oscillated from 4 N to 100 N at 1 Hz. Each specimen experienced 100,000 load cycles.

The toothbrushing cycle was done with a total of 3,000 reciprocal strokes. Teeth were brushed by a brushing machine (KMC-1205S-O, Vision Scientific, Korea) using a soft toothbrush (Oral-B contura, Soft, Oral-B Laboratories, U.S.A.) and dentifrice slurry (PERIOE Cavity Care Tooth Paste, LG Household & Health Care Ltd., Korea) with a paste to water ratio of 5:1.

The aging in deionized water for subgroups E was done in deionized water at 37℃ for six months.

All specimens were dried superficially and entirely covered with two coats of nail varnish except for a 1mm window around the restoration margins.

The teeth were immersed in a 2% methylene blue solution for 24 hours at room temperature and then washed under running water and dried. They were sectioned at the center of the cavity in a buccolingual direction along their longitudinal axis with a low-speed diamond saw. To evaluate the extent of dye penetration, the sectioned specimens were viewed using a stereomicroscope (Olympus SZ-PT, Olympus Co, Japan) at a 2× magnification. The occlusal and cervical margins were analyzed separately, and dye penetration was scored as follows: 0 = absence of dye penetration; 1 = dye penetration up to one-third of the extension of the walls; 2 = dye penetration from one-third to two-thirds of the extension of the wall; 3 = dye penetration to more than two-thirds of the extension of the walls.

Selected samples were prepared for scanning electron microscopic examination to visually investigate the tooth-restoration interface.

The data were analyzed with nonparametric statistical methods. The Kruskal-Wallis test and the Mann-Whitney U test were used to identify any statistically significant differences among the groups.

**Table 1.** Aging treatments used in this study

| Group | | Aging treatments |
|---|---|---|
| Without surface sealing | IA | No further treatment (only thermocycling) |
| | IB | Toothbrushing (total 3,000 cycles during 60 minutes) |
| | IC | Load cycling (total 100,000 cycles with 4- to 100-N load at a rate of 1 Hz) |
| | ID | Toothbrushing followed by load cycling (as described for group B and C) |
| | IE | Aging treatment in 37℃ deionized water for 6 months |
| With surface sealing | IIA | No further treatment (only thermocycling) |
| | IIB | Toothbrushing (total 3,000 cycles during 60 minutes) |
| | IIC | Load cycling (total 100,000 cycles with 4- to 100-N load at a rate of 1 Hz) |
| | IID | Toothbrushing followed by load cycling (as described for group B and C) |
| | IIE | Aging treatment in 37℃ deionized water for 6 months |

## Ⅲ. RESULTS

Table 2 summarizes the frequency of microleakage scores of different groups at the occlusal and cervical margins.

In groups without surface sealing, there was no significant difference in microleakage at the occlusal and cervical margins according to aging treatments (groups IA, IB, IC, ID, IE; $p>0.05$). In the occlusal margins of the groups with surface sealing (groups IIA, IIB, IIC, IID, IIE), no significant difference was observed according to aging treatments ($p>0.05$). However, in the cervical margins of the surface sealing groups, microleakage significantly increased after load cycling or aging in deionized water for six months (groups IIC, IID, and IIE vs. groups IIA and

**Table 2.** Distribution of Microleakage Scores (n=10)

| Subgroups | Microleakage Score | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Occlusal margins | | | | Cervical margins | | | |
| | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 |
| IA | 3 | 6 | 1 | 0 | 1 | 3 | 3 | 3 |
| IB | 3 | 6 | 1 | 0 | 1 | 1 | 2 | 6 |
| IC | 2 | 5 | 3 | 0 | 1 | 4 | 2 | 3 |
| ID | 0 | 8 | 1 | 1 | 1 | 5 | 0 | 4 |
| IE | 3 | 1 | 2 | 4 | 2 | 1 | 1 | 6 |
| IIA | 6 | 4 | 0 | 0 | 4 | 5 | 1 | 0 |
| IIB | 2 | 8 | 0 | 0 | 6 | 3 | 1 | 0 |
| IIC | 5 | 5 | 0 | 0 | 1 | 2 | 0 | 7 |
| IID | 4 | 6 | 0 | 0 | 0 | 6 | 2 | 2 |
| IIE | 5 | 3 | 0 | 2 | 0 | 2 | 0 | 8 |

**Table 3.** Statistical comparison of microleakage scores with regard to surface sealing

| Groups | IA-IIA | IB-IIB | IC-IIC | ID-IID | IE-IIE |
|---|---|---|---|---|---|
| Occlusal margins | - | - | - | * | - |
| Cervical margins | * | * | - | - | - |

*: $p<0.05$, -: $p>0.05$.

**Table 4.** Statistical comparison of microleakage scores with regard to aging treatment (occlusal margins/cervical margins)

| Without surface sealing | IA | IB | IC | ID | IE |
|---|---|---|---|---|---|
| IA | | | | | |
| IB | -/- | | | | |
| IC | -/- | -/- | | | |
| ID | -/- | -/- | -/- | | |
| IE | -/- | -/- | -/- | -/- | |
| **With surface sealing** | **IIA** | **IIB** | **IIC** | **IID** | **IIE** |
| IIA | | | | | |
| IIB | -/- | | | | |
| IIC | -/* | -/* | | | |
| IID | -/* | -/* | -/- | | |
| IIE | -/* | -/* | -/- | -/* | |

*: $p<0.05$, -: $p>0.05$.

IIB; $p<0.05$).

The no-further-treatment group and the toothbrushing group with surface sealing (groups IIA and IIB) showed less microleakage than the corresponding groups without surface sealing (groups IA and IB; $p<0.05$). However, the surface-sealed groups with load cycling (groups IIC and IID) or aging in deionized water (group IIE) showed no significant differences in microleakage from the corresponding groups without surface sealing (groups IC, ID, and IE, respectively; $p>0.05$)(Tables 2-4).

Figures 1-6 show photomicrographs of the margins with various degrees of microleakage. Figures 1 and 2 show a good adaptation of group IA and IIA restorations to the teeth at the occlusal and cervical margins. In Figure 3, an opened gap between dentin and composite resin in the cervical margin was detected in spite of the application of the surface sealant. Figure 4 demonstrates that the cervical margin is more vulnerable to stresses from the aging treatments than the occlusal margin. Figure 5 shows that a portion of the surface sealant layer is detached from the composite resin after aging. The surface sealant protected the surface of the restoration at the occlusal margin, but some microleakage can be observed at the cervical margin. Figure 6 shows the failure of the restoration to maintain its marginal integrity after aging process in water.

## Ⅳ. DISCUSSION

Thermocycling, toothbrushing, and load cycling procedures in this study are used to simulate intraoral conditions. The temperature range of 55±2℃ and 5±2℃ that was used in this study corresponds to the extremes of temperatures that could be experienced in the oral environment[25]. The 3,000 stroke figure of toothbrushing simulated the use of a toothbrush for approximately three to four months[26]. The load cycling (total 100,000 cycles with a 4- to 100-N load at a rate of 1 Hz) applied to the samples in this study approximately corresponds to at least 12-14 weeks of clinical chewing[27].

Each of the no-further-treatment groups and toothbrushing groups with surface sealing (groups IIA and IIB) showed less microleakage than the groups without surface sealing (groups IA and IB). Abrasive wear occurred on the sealed surface, but the dentin remained sealed and protected by the integrity of the hybrid layer, with effective penetration of the surface sealant in the interface. Thus, the surface sealant retained its effectiveness after toothbrushing. When air bubbles or humidity of debris are present, a low viscosity resin is not able to penetrate the gaps thoroughly due to the incomplete wetting of the surface, and only covers them. In this case, brushing may cause the loss of the fluid resin layer[11]. Therefore, it is critical that the area to be surface-sealed be meticulously cleaned and dried to improve wetting.

Load cycling significantly increased microleakage in the cervical margins of the groups with surface sealing. The groups with surface sealing subjected to load cycling (groups IIC and IID) showed no significant differences in microleakage compared to the corresponding groups without surface sealing (groups IC and ID). The results of this study therefore suggest that the surface sealant, by infiltrating through the gap in the cervical margin, was effective on reducing microleakage at initial stage, but that its elastic modulus and bond strength were not sufficient to overcome the stress generated by the cuspal flexure of occlusal load. According to Jang et al.[28], adding eccentric oblique load cycling significantly increased the microleakage of class V restorations. Also, Mandras et al.[29] reported that microleakage in the gingival margins increased significantly after load cycling.

Like load cycling, aging process in deionized water increased microleakage in the cervical margins of the group with surface sealing, and the group with surface sealing that underwent aging process in deionized water (group IIE) showed no significant difference in microleakage to the group without surface sealing (group IE). Bonding agents and surface sealants do not usually contain filler particles, in order to maintain the fluidity of the resin. As a result, bonding agents and surface sealants have an increased potential to absorb water in comparison with filled restorative composite resin materials[30]. The water uptake and swelling of the resin might induce a loosening of the restorative resin-surface sealant bonding, and the surface sealant no longer had a positive effect on microleakage.

Mohsen et al.[31] stated that subsequent absorption of moisture caused more water molecules to break the hydrogen bonds existing in the UDMA polymer network. This, in turn, forced the chains to large mutual distances and exerted a plasticizing effect. This phenomenon may cause degradation and therefore affect the physical properties. Ferracane et al.[32] said that the hardness of the most composite resins was reduced after six months of water sorption.

The swelling seen in surface sealants or bonding agents may be exaggerated due to the presence of an air-inhibited surface layer[33]. Clinically, surface sealants may not polymerize completely, and may degrade when exposed to the oral environment. Recently, a surface sealant without this oxygen-inhibition layer was released. This product, Biscover, is expected to be more resistant to swelling in water, and to have a harder and smoother surface. A future study should investigate the positive effects of a surface sealant that does not form an oxygen-inhibition layer.

The thickness of surface sealant was measured in recent studies. Song[34] stated that the mean thickness of the surface sealant in artificial cylinder specimens was 11.73(±2.36)㎛. Bertrand et al.[35] claimed that the thickness of surface sealant in artificial cylinder specimens showed wide variations between different samples and also between different areas of the same sample (0~70 ㎛). These measurements of thickness show the difficulty or even impossibility of obtaining a regular surface using a brush application. Moreover, using this method to apply a liquid resin to the curved surface of composite resin in clinical situations, even though it is the only clinical method presently available, is bound to produce inconsistencies in thickness compared to these in vitro studies, especially at the cervical margins. This might be an important factor in the rapid degradation of the surface sealant layer at the cervical margins during aging.

In the present study, the groups with surface sealing (group II) were more susceptible to load cycling or aging in deionized water than groups without surface sealing (group I). There was no significant difference in microleakage after being subjected to toothbrushing, load cycling or aging process in deionized water in groups without surface sealing (groups IA, IB, IC, ID, and IE), but additional load cycling or aging process in deionized water significantly increased microleakage (groups IIC, IID, and IIE vs. groups IIA and IIB) in the groups with surface sealing. Munro et al.[13] reported that etching the gingival margin before surface sealing could involve some risk of ditching the cementum and opening dentinal tubules. This procedure might be one of the causes of increased susceptibility to load cycling or aging process in deionized water seen in group II. However, etching should be used before surface sealing, according to the manufacturers' directions, to enhance the resin adhesion and to remove the any acid-soluble substances that may have contaminated the restoration and adjacent tooth structure during restoration, finishing, and polishing[36]. If every specimen in the groups without surface sealing (groups IC and ID) had experienced over 100,000 load cycles, the added load cycling might have significantly increased microleakage.

Concerning the longevity of the surface sealant, de Wet and Fereira[22] showed that the surface glaze over composite resin lasts from six months to one year in vivo. According to Dickinson and Leinfelder[12], the surface penetration sealant's effectiveness could be enhanced if the material were reapplied biannually. Periodical reapplication of the surface sealant is considered one method to compensate for the loss of marginal integrity caused by the occlusal load and water absorption[17]. In this study, the positive effect of the surface sealant on microleakage did not remain after six months. Thus, it can be proposed that surface sealants may need to be reapplied at least every six months.

In the present study, class V cavities were restored and surface sealed on extracted teeth in vitro. Because clinical studies are nearly impossible to perform while controlling the conditioning factors and assessing microleakage by sectioning the teeth, in vitro studies are of significant value. Moreover, in vitro studies have the advantages of time and cost. However, although the experimental methods were the same as clinical procedures, the bonding of the restorative material to the vital tooth is inimitable, and the outward flow of pulpal fluid may inhibit the penetration of the surface sealant at the restoration margins. In the future, it will be necessary to develop new experimental methods that allow the precise control of influential factors and that better imitate the in vivo environment.

## Ⅴ. CONCLUSIONS

This in vitro study was performed to assess the effect of surface sealing on the microleakage of class V composite resin restorations that underwent several aging treatments. Class V composite resin restorations with or without surface sealing were subjected to five aging treatments (no further treatment, toothbrushing, load cycling, toothbrushing followed by load cycling, and aging in deionized water for six months). The microleakage was assessed by a methylene blue dye perfusion test.

The following results were obtained:

1. At the occlusal and cervical margins of the groups without surface sealing, there was no significant difference in the microleakage scores between the various aging treatments (groups IA, IB, IC, ID, and IE; $p>0.05$).
2. In the occlusal margins of the groups with surface sealing (groups IIA, IIB, IIC, IID, and IIE), no significant differences were observed among the various aging treatments ($p>0.05$).
3. In the cervical margins of the groups with surface sealing, microleakage significantly increased after load cycling or aging process in deionized water for six months (groups IIC, IID, and IIE vs. groups IIA and IIB; $p<0.05$).
4. The no-further-treatment and toothbrushing groups with surface sealing (groups IIA and IIB) showed less microleakage than the groups without surface sealing (groups IA and IB; $p<0.05$).
5. The surface-sealed groups with load cycling (groups IIC and IID) or aging treatments in deionized water (group IIE) showed no significant difference in microleakage from the corresponding groups without surface sealing (groups IC, ID, and IE, respectively; $p>0.05$).

This study suggests that infiltration of the surface sealant through the gap in the cervical margin exerted a positive effect on microleakage at the initial stage, but that the effect was not sufficient to overcome the stress generated by the cuspal flexure of occlusal load and by the water absorption.

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# FIGURES ①

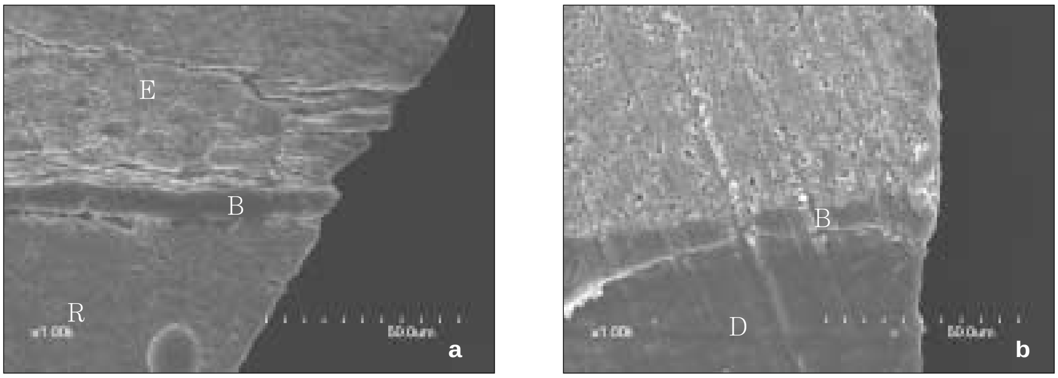


**Fig. 1.** SEM images of the occlusal margin (a) and the cervical margin (b) of group IA. E, enamel; D, dentin; B, bonding agent; R, composite resin (original magnification 1,000×).

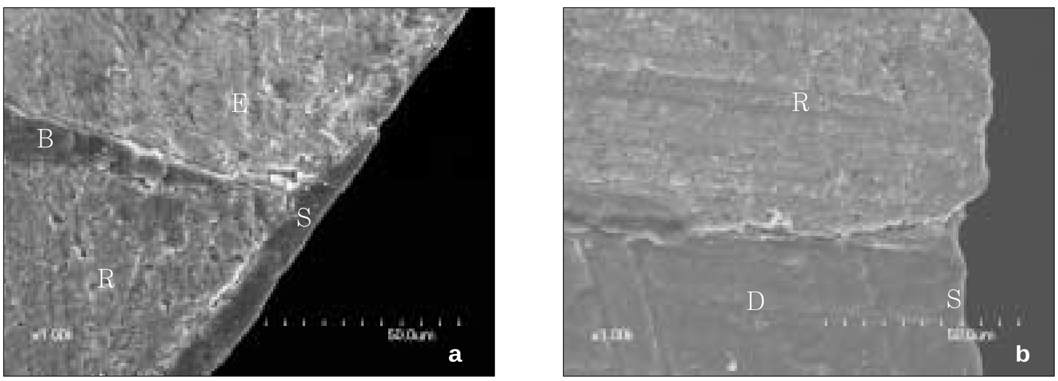


**Fig. 2.** SEM images of the occlusal margin (a) and the cervical margin (b) of group IIA. E, enamel; D, dentin; B, bonding agent; R, composite resin; S, surface sealant (original magnification 1,000×).

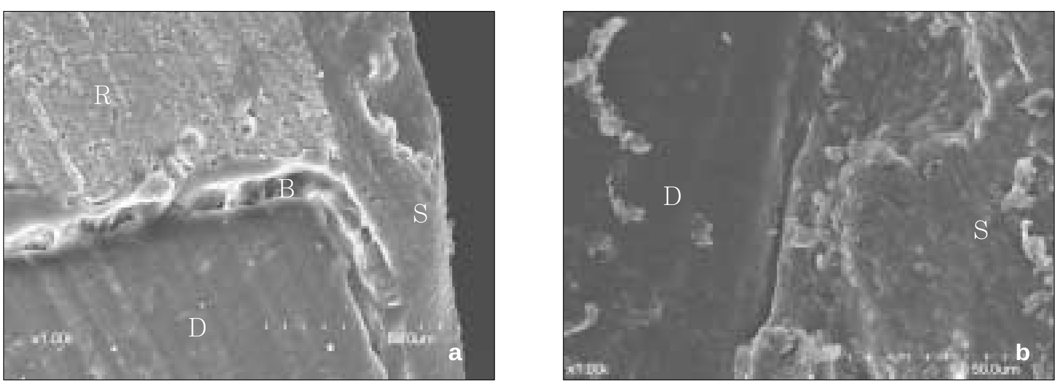


**Fig. 3.** SEM images of the cervical margin (a) and the interface of dentin and surface sealant of group IIA (b). D, dentin; R, composite resin; S, surface sealant (original magnification 1,000×).

# FIGURES ②

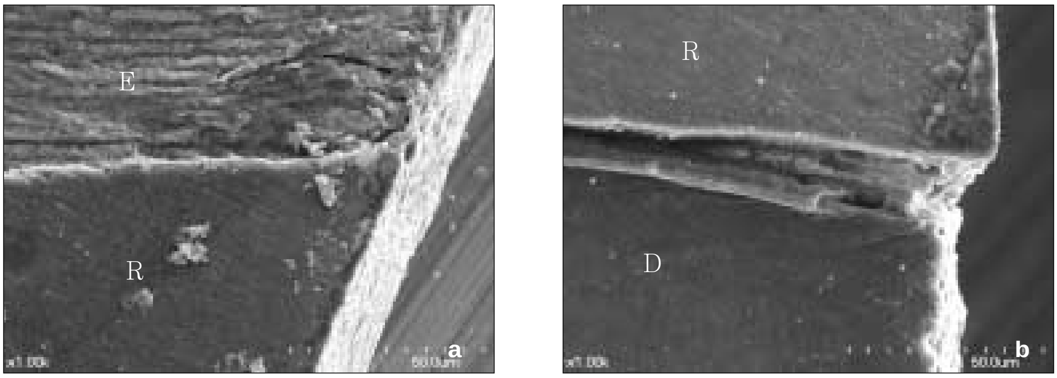


**Fig. 4.** SEM images of the occlusal margin (a) and the cervical margin (b) of group ID. E, enamel; D, dentin; R, composite resin (original magnification 1,000×).

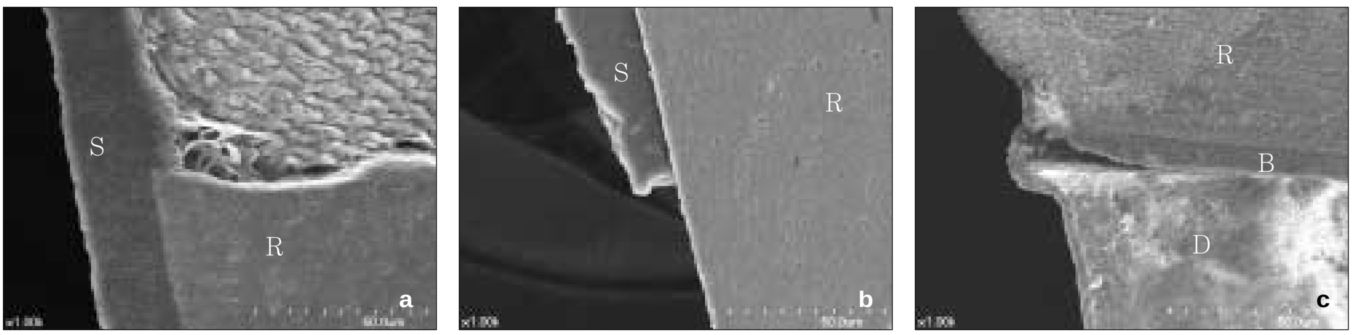


**Fig. 5.** SEM images of the occlusal margin (a), composite resin layer (b), and cervical margin (c) of group IID. E, enamel; D, dentin; B, bonding agent; R, composite resin; S, surface sealant (original magnification 1,000×).

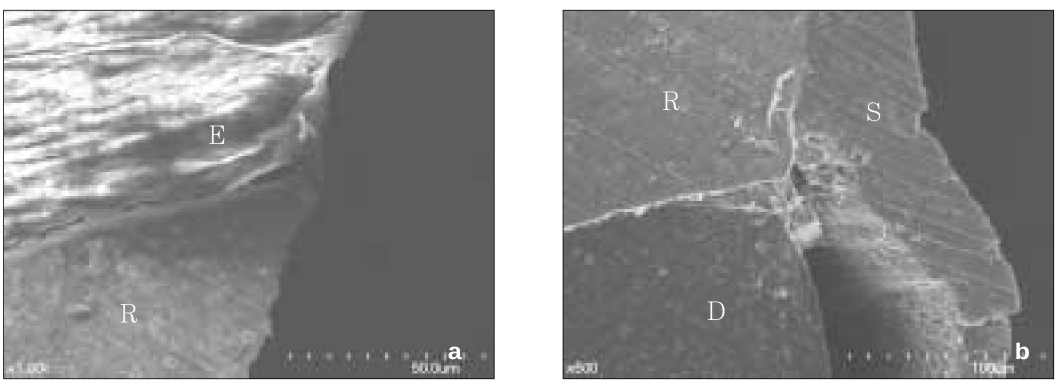


**Fig. 6.** SEM images of the occlusal margin (a) at original magnification 1,000× and the cervical margin (b) at original magnification 500× of group IIE. E, enamel; D, dentin; R, composite resin; S, surface sealant.

국문초록

# 제V급 복합레진 수복물의 표면전색이 미세변연누출에 미치는 효과

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본 연구는 다양한 순환 및 시효 조건 하에서 제V급 복합레진 수복물의 표면전색이 미세변연누출에 미치는 효과에 대해 알아보고자 하였다.

100개의 건전한 소구치의 협면에 제V급 와동을 형성하고 제조사의 지시대로 광중합형 복합레진으로 수복하였다. 무작위로 나누어 표면전색을 시행하지 않는 I군과 표면을 산부식 후 표면전색을 시행한 II군으로 설정한 후 열순환(thermocycling)을 하였다. 각 군에서 하위군(A군= 열순환 외 다른 시효조건이 없는 군, B군=칫솔질군, C군=부하순환군, D군=칫솔질과 부하순환을 모두 시행한 군, E군=6개월간 증류수에 보관한 군)으로 나누어 각각에 맞는 시효조건을 시행하였다. 2% methylene blue 용액에 침윤시켜 변연의 미세누출정도를 평가하여 다음과 같은 결과를 얻었다.

1. 표면전색을 시행하지 않은 군의 교합변연과 치은변연에서 시효조건에 따른 미세누출의 유의한 차이는 보이지 않았다($p>0.05$).
2. 표면전색을 시행한 군의 교합변연에서는 시효조건에 따른 미세누출의 유의한 차이가 없었다($p>0.05$).
3. 표면전색을 시행한 군의 치은변연에서는 부하순환이나 6개월간 증류수에서 보관하는 시효과정을 거친 군에서 미세누출이 유의하게 크게 나타났다($p<0.05$).
4. 시효조건이 없는 군과 칫솔질군의 경우, 표면전색을 시행한 군이 표면전색을 시행하지 않은 군에 비해 유의하게 적은 미세누출결과를 보였다($p<0.05$).
5. 부하순환을 시행한 군과 6개월간 증류수에서 보관한 경우에는 표면전색을 시행한 군과 표면전색을 시행하지 않은 군 사이에 미세누출의 차이가 있었지만 유의차가 없었다($p>0.05$).

따라서 이 연구의 결과는 변연부분의 미세간격으로 침투한 표면전색제가 처음에는 미세누출을 감소하는데 효과를 보여주었으나, 교합시 교두가 휘어져서 생기는 응력과 장기간의 수분흡수로 인한 변화를 견디기에 불충분함을 보여주었다.

**주요어** : 표면전색, 미세변연누출, 칫솔질, 부하순환, 수분흡수