the Journal of Contemporary Dental Practice at www.thejcdp.com
Volume 9 Number 7 November 1, 2008

# Influence of Location of the Gingival Margin on the Microleakage and Internal Voids of Nanocomposites

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## Abstract

**Aim:** The aim of this *in vitro* study was to investigate the cervical microleakage and internal voids of nanocomposites comparing them with a hybrid composite in Class II restorations with the margins located coronal and apical to the cementoenamel junction (CEJ).

**Methods and Materials:** Standardized MOD cavities (one cervical margin located in dentin, one in enamel) were prepared in 40 extracted human molars and divided into four groups according to the composite used to restore them (n=10/group). Group 1: Adper Single Bond2/Filtek Supreme XT; Group 2: Excite/Tetric EvoCeram; Group 3: Prime & BondNT/Ceram X; and Group 4 (control) Adper Single Bond2/Filtek Z250. Groups were further divided into subgroups A and B. The "A" subgroups represent the level of the location of the cervial margin at 1 mm coronal to the CEJ, and the "B" subgroups represent the level of the cervical margin located 1 mm apical to the CEJ. After restoration of the cavities with nanocomposites, thermocycling, and immersion in 0.5% basic fuchsin, the dye penetration and internal voids were evaluated under a stereomicroscope. Data were analyzed with the Mann-Whitney U and Kruskal-Wallis tests with the Bonferroni correction for microleakage and with the Chi-square test for internal voids ($p<0.05$).

**Results:** The microleakage in the A subgroups was statistically significantly lower then B subgroups ($p<0.05$). No statistically significant difference was observed in terms of interface, cervical, and occlusal voids for all groups ($p>0.05$). No significant difference was observed between each group for three voids in all groups ($p>0.05$).

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**Conclusion:** The location of the gingival margin affects the microleakage of nanocomposites but has no significant affect on the internal voids.

**Clinical Significance:** Gingival margin located 1 mm coronal to the CEJ provided a reduction in cervical microleakage in nanocomposite restorations.

**Keywords:** Nanocomposite, gingival level, void, microleakage

**Citation:** Ozel E, Korkmaz Y, Attar N. Influence of Location of the Gingival Margin on the Microleakage and Internal Voids of Nanocomposites. J Contemp Dent Pract 2008 November; (9)7:065-072.

## Introduction

Following the development of new adhesive systems and the improvement of resin composite properties, esthetic restorations have been commonly used for posterior teeth.[1,2,3] On the other hand, many clinical and material limitations have restricted the universal use of resin composites as a posterior restorative material.[3,4]

One of the most important advances in the last few years has been the application of nanotechnology to resin composites. Nanotechnology is based on the production of functional materials and structures in the range of 1 to 100 nanometers using various physical and chemical methods. These novel resin composites containing nanoparticles offer several advantages such as reduced polymerization shrinkage, increased mechanical properties, improved optical characteristics, better gloss retention, and diminished wear.[5,6]

When resin composite is inserted into a cavity preparation, it bonds to the prepared surfaces using an adhesive system, however, during light activation, a competition occurs between the shrinkage force of the composite and bond strength to the dental structure.[7] For this reason, the initial polymerization shrinkage of the composite resin has led to separation of the resin from the cavity walls and the formation of gaps between cavity and composite resin.[8,9] If the bond strength is weaker than the shrinkage force, this union may fracture forming a gap resulting in marginal microleakage that allows for the passage of bacteria, fluids, molecules, or ions between the cavity surfaces and the restorative material resulting in the failure of the restoration.[10]

Microleakage is frequently observed at the cervical margin of a proximal box. The absence of enamel at the gingival margin creates a dependence on adhesion of restorative materials to the cementum/dentin tissue.[11] Another potential clinical problem associated with Class II cavity preparations is the creation of voids along the gingival margin that results from the inability to adequately adapt the materials to margins before curing.[3] Novel composites with nano particles may decrease the possibility of internal voids.

The purpose of this *in vitro* study was to investigate cervical microleakage and internal voids of different nanocomposites compared with Class II hybrid composite restorations with the margins coronal and apical to the cementoenamel junction (CEJ).

## Methods and Materials

### Sample Preparations

Forty human third molars without any defects were immersed in a 0.5% thymol solution until starting the experiment. All the molars were prepared with standardized Class II MOD as follows:

- **Occlusal Segments:** 2 mm in depth and 2 mm in bucco-lingual width
- **Proximal Boxes:** 2 mm in bucco-lingual width and 1.5-2 mm in the pulpal direction (mesio-distal depth)

The cavity preparations were prepared with a high-speed handpiece using water spray and a #1090 diamond fissure bur (Diatech Dental AG, Heerbrugg Switzerland). New burs were used after every five preparations. The cervical wall (floor) of the mesial proximal box was located 1 mm coronal to the CEJ (in enamel) while the cervical wall of the distal proximal box was placed 1 mm apical to the CEJ (in dentin) in each cavity preparation. None of the cavosurface line angles of these preparations had beveled edges. The teeth were randomly divided into four groups of ten teeth each.

### Restorative Procedures

The restorations were placed by a single operator according to manufacturers' instructions. The properties of restorative materials and manufacturers are presented in Table 1.

The MOD specimens in each group were then processed by etching the preparations in each group with each manufacturer's acid etching gel for 15 seconds, rinsed with water for 20 seconds, and gently air dried to leave the surfaces moist. Then each group of specimens was restored as follows:

**Group 1:** Adper Single Bond 2 (3M ESPE, St. Paul, MN, USA) was applied and cured for 10 seconds. A nanocomposite Filtek Supreme XT (3M ESPE, St. Paul, MN, USA) was placed and polymerized for 20 seconds/increment.

**Group 2:** Excite (Ivoclar-Vivadent, Schaan, Liechtenstein) was placed and cured for 20 seconds. A nanohybrid composite Tetric EvoCeram (Ivoclar-Vivadent, Schaan, Liechtenstein) was applied and polymerized for 20 seconds/increment.

**Group 3:** Prime & Bond NT (Dentsply, De Trey, Konstanz, Germany) was applied and cured for 10 seconds. A nano-ceramic restorative material Ceram X (Dentsply, De Trey, Konstanz, Germany) was placed and polymerized for 20 seconds/increment.

**Group 4 (control):** Adper Single Bond 2 (3M ESPE, St. Paul, MN, USA) was placed and cured for 10 seconds. A hybrid composite Filtek Z250 (3M ESPE, St. Paul, MN, USA) was applied and polymerized for 20 seconds/increment.

A metal matrix system (Tofflemire, Teledyne Water Pik, Ft. Collins, CO, USA) was then adapted to the prepared tooth before incremental insertion and light curing of the restorative material. Composite resins were placed in 2 mm increments for all groups. All materials were polymerized using a halogen light curing unit (PolyLUX II, KaVo, Biberach, Germany).

All groups were divided into two subgroups (1A, 1B, 2A, 2B, 3A, 3B, 4A, and 4B). The "A" subgroups represent the level of the cervical wall which was located 1 mm coronal to the CEJ (in enamel) and the "B" subgroups represent the cervical wall level located 1 mm apical to the CEJ (in dentin).

### Finishing and Polishing Procedures

Finishing procedures were performed with a fine diamond bur (Diatech Dental AG, Heerbrugg Switzerland), then polished with a graded series of Sof-Lex discs (3M ESPE, St. Paul, MN, USA). Care was taken to avoid polishing the cervical margin.

### Assessment of Microleakage (Microleakage Test)

All samples were stored in distilled water at 37ºC for 24 hours, then thermocycled 500 times each at 5ºC and 55ºC (dwell time of 30 seconds). The specimens were subsequently sealed with a composite resin (TPH Spectrum, Dentsply deTray, Konstanz, Germany) at the root apices, and two coats of nail varnish were applied on the tooth within 1 mm of the restoration margins. The restorations were then immersed in 0.5% aqueous basic fuchsin dye for 24 hours. They subsequently were rinsed under running water to remove dye and dried at room temperature.

All samples were sectioned longitudinally through their centers mesial to distal using a water-cooled, slow-speed diamond saw (Isomed, Buehler Ltd, Lake Bluff, IL, USA). The lengths of the dye

Table 1. Properties of the materials utilized in the study.

| Resin Composite | Composition | Type | Filler Content % (w/w) % (v/v) | Bonding Agent |
|---|---|---|---|---|
| **Filtek Supreme XT** (3M ESPE, St. Paul, MN, USA) | **Matrix**: Bis-phenolA diglycidylmethacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA), bisphenol A polyethylene glycol diether dimethacrylate **Filler:** Silica nanofillers (5-75 nm) Zirconia/silica nanoclusters (0.6-1.4 μm) | Nanofilled | 78.5 59 | **Adper Single Bond 2** (3M ESPE, St. Paul, MN, USA) |
| **Tetric EvoCeram** (Ivoclar Vivadent, Schaan, Liechtenstein) | **Matrix:** Dimethacrylates, additives, catalysts, stabilizers, pigments **Filler:** Barium glass, ytterbium trifluoride, mized oxide, prepolymers | Nanohybrid | 82.5 68 | **Excite** (Ivoclar Vivadent, Schaan, Liechtenstein) |
| **Ceram X** (Dentsply DeTrey, Konstanz, Germany) | **Matrix:** Methacrylate modified polysiloxane, dimethacrylate resin, fluorescent pigment, UV stabilizer, stabilizer, camphorquinone, ethyl-4 (dimethylamino) benzoate, iron oxide pigments, titanium oxide pigments, aluminum sulfo silicate pigments **Filler:** Barium-aluminum-borosilicate glass (1.1-1.5 μm) Methacrylate functionalized silicon dioxide nano filler (10 nm) | Nanohybrid | 76 57 | **Prime & Bond NT** (Dentsply DeTrey, Konstanz, Germany) |
| **Filtek Z250** (3M ESPE, St. Paul, MN, USA) | **Matrix:** Bis-phenolA diglycidylmethacrylate (Bis-GMA), urethane dimethacrylate (UDMA), Ethoxylated bisphenolA dimethacrylate (Bis-EMA) **Filler:** zirconia/silica (0.01-3.5 μm) | Hybrid | 66 60 | **Adper Single Bond 2** (3M ESPE, St. Paul, MN, USA) |

penetration of cervical margins were examined with a stereomicroscope (X40 magnification) (Leica MS5, Singapore, Singapore) by two examiners and cervical marginal microleakage and internal voids (at the gingival wall interface and in the cervical and the occlusal parts) were recorded.

The scale of dye penetration and the definition of the scores for cervical marginal microleakage are presented in Table 2.[12]

The schematic view of the evaluation is exhibited in Figure 1.

The scoring system for internal voids was modified from the Chuang et al.[13] study. The description of the location of voids along with a semi-quantitative analysis of them are shown in Table 3. The evaluation of the voids was carried out in three different parts of the restoration.

## Statistical Analysis

Data were analyzed with the Mann-Whitney U and Kruskal-Wallis tests with the Bonferroni correction for pair wise comparisons at a significance level of $p<0.05$ for microleakage and with the Chi-square test for internal voids (three separated parts).

**Table 2. Definiton of the scores for cervical marginal microleakage.**

| | Scores | Definition of the Scores |
|---|---|---|
| **Cervical Marginal Microleakage** | Score 0 | No dye penetration |
| | Score 1 | Dye penetration limited to enamel |
| | Score 2 | Dye penetration beyond to the dentino-enamel junction but limited to 2/3 cervical wall length |
| | Score 3 | Dye penetration beyond 2/3 of the cervical wall length |

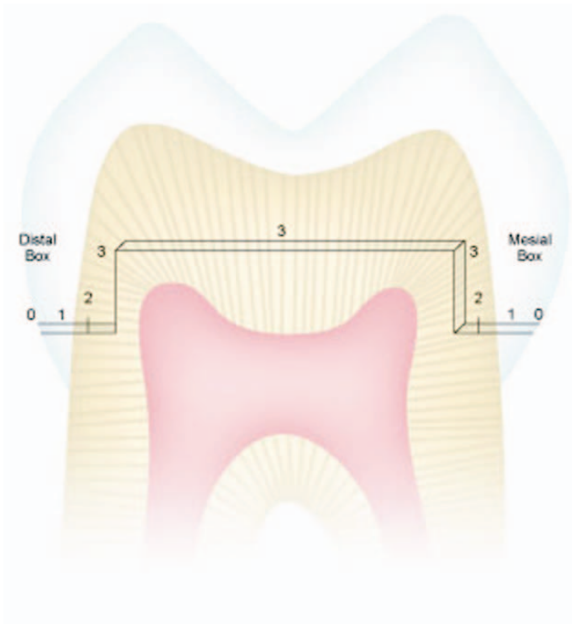


**Figure 1.** Schematic view of the evaluation.

**Table 3. Scoring system for internal voids.**

| Voids | Scores | Definition |
|---|---|---|
| Interface Void (Gingival Margin-Resin Interface) | Score 0 | No void |
| | Score 1 | Some voids exist |
| Cervical Void (Cervical Half) | Score 0 | No void |
| | Score 1 | Some voids exist |
| Occlusal Void (Occlusal half) | Score 0 | No void |
| | Score 1 | Some voids exist |

## Results

The observed microleakage and internal void scores are shown in Tables 4 and 5, respectively.

The microleakage in Groups 1A, 2A, 3A, and 4A was statistically significantly lower than Groups 1B, 2B, 3B, and 4B ($p<0.05$). There was no statistically significant difference between both nanocomposites and the hybrid composite regardless of the location of gingival wall between them in A and B groups independently in terms of microleakage ($p>0.05$).

No statistically significant difference was observed in terms of interface, cervical, and occlusal voids

**Table 4. Microleakage scores.**

| Groups | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Group 1A | 8 | 0 | 1 | 1 |
| Group 1B | 4 | 1 | 0 | 5 |
| Group 2A | 9 | 0 | 1 | 0 |
| Group 2B | 2 | 0 | 1 | 7 |
| Group 3A | 9 | 0 | 1 | 0 |
| Group 3B | 2 | 3 | 3 | 2 |
| Group 4A | 9 | 0 | 1 | 0 |
| Group 4B | 5 | 0 | 2 | 3 |

**Table 5. Scores of three parts of internal voids.**

| Groups | Interface Void | | Cervical Void | | Occlusal Void | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 0 | 1 | 0 | 1 |
| Group 1A | 9 | 1 | 10 | 0 | 10 | 0 |
| Group 1B | 8 | 2 | 10 | 0 | 9 | 1 |
| Group 2A | 10 | 0 | 10 | 0 | 10 | 0 |
| Group 2B | 7 | 3 | 8 | 2 | 9 | 1 |
| Group 3A | 9 | 1 | 10 | 0 | 10 | 0 |
| Group 3B | 7 | 3 | 9 | 1 | 10 | 0 |
| Group 4A | 9 | 1 | 9 | 1 | 8 | 2 |
| Group 4B | 9 | 1 | 7 | 3 | 9 | 1 |

for all groups (p>0.05). When the interface, cervical, and occlusal voids were compared, there was no statistically significant difference between them for all groups (p>0.05). The comparison between locations of the gingival margins (1 mm coronal to the CEJ or 1 mm apical to the CEJ) exhibited no statistically significant difference in terms of internal voids (interface-interface, cervical-cervical, occlusal-occlusal) (p>0.05).

## Discussion

It is well known marginal microleakage is one of the major disadvantages of resin composite restorations. This fact results from failure of the material to adapt to tooth structure, especially at the gingival margin. As a layer of resin composite is inserted in the cavity and polymerized, a competition between polymerization shrinkage of the composite and adhesion to the substrate begins. Polymerization shrinkage causes stresses which are critical to adhesion between the resin composite and the tooth structure. This shrinkage stress depends on factors such as cavity size and shape, substrate type, location of the margins, restorative material, and the technique used for placement and polymerization.[8,14] When shrinkage stresses are stronger than the bond strength between the resin and adhesive system, the tooth-restoration interface can fracture causing a gap that will allow marginal microleakage.[7]

In order to achieve similar clinical conditions the restorations were thermocycled. This method simulates “aging” of the restoration through thermal oscillations, similar to restorations in actual clinical conditions that could influence the outcome of an evaluation of microleakage.[15,16]

The incremental technique was used in this study to place resin composite materials in 2 mm thick increments to achieve standardization. When the increments were thicker than 2 mm, an increase in polymerization stress occurs along with a poorer rate of conversion, mainly cervically, where the distance from the light source is greater than the ideal.[3] For adequate interproximal contact, a metalic matrix was used, therefore, light curing can only be performed from the occlusal surface. As a result, polymerization shrinkage is directed away from the gingival margins of the prepartions.[3]

Dye penetration studies are the most popular technique used in microleakage investigations. In the present study a dye penetration test was used because this test provided a simple, relatively cheap, quantitative, and comparable method of evaluating the performance of various restoration techniques.[17]

One of the weakest links of Class II composite resin restorations is microleakage at the gingival margin of the proximal box. The absence of enamel at the gingival margin leads to the adhesion of composite materials to cementum/dentin which is an unstable substrate.[11,18] While enamel is almost exclusively an inorganic tissue, dentin is less mineralized and contains more moisture which can cause variations in adhesion.[19] In Class II cavities where the cervical margin is located on the root dentin apical to the CEJ, contraction forces may exceed the adhesive strength to dentin of the bonding agents producing a gap. Gap formation allows microleakage.[20] Although some degree of microleakage will occur with most dental materials, slight leakage can be tolerated by the pulp and irritants are often removed by pulpal blood flow.[21] However, in some circumstances microleakage can become a source of postoperative sensitivity, recurrent caries, and lead to eventual restoration failure.[21]

Enamel is a more reliable substrate than dentin in direct adhesive Class II restorations because of its homogeneous structure and hydrophobic character.[14,22,23] Therefore, enamel margins generally produce consistent bonding and microleakage is less likely to occur than with dentinal margins.[19] This fact is also due to the strong adhesion achieved with inorganic tissue.[18] However, margins are frequently placed apical to the CEJ on dentin or cementum where moisture control and access for finishing are more problematic. Dentin bonding is more difficult because the heterogeneous nature of the tissue requires the bonding system to accommodate simultaneously the properties of the hydroxyapatite, collagen, smear layer, dentinal tubules, and fluids. Consequently, the ability to achieve an effective seal at the gingival margin becomes even more important in terms of longevity of a resin restoration.[21]

There are potential clinical problems associated with the use of resin-based composites in Class II cavity preparations.[24] Voids in gingival marginal areas can result from the inability to adequately adapt the materials to margins before curing.[25] Only a few studies include a correlation between microleakage and the presence of voids. Chuang et al.[13] found a reduction in the presence of internal restoration voids when using flowable resin composites as a lining material for Class II resin composites. The incidence of internal voids was significantly reduced at both the restoration's interface and within its mass.[24] In that study no significant difference was observed in terms of voids.

Major marginal microleakage occuring at the gingival level located in dentin or cementum has been reported.[16,26] The reason for this fact is these two structures do not offer the same conditions for adhesion to resin composites as does enamel which yields better results.[23] Additionally, difficulty accessing the proximal boxes of preparations and the control of moisture are challenging factors during the restorative procedure.[27] In the present study the gingival level of the cavities were different. Half of the cavities were located 1 mm coronal to the CEJ (wall in enamel) and the other half were located 1 mm apical to the CEJ (wall in dentin).

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 tissue.[18] For dentin, on the other hand, the values of the internal stress are often larger than the bond strength to dentin walls[28] and, consequently, a gap may form at the interface.[29] This polymerization shrinkage, which is inherent to composites, is considered mainly responsible for the gap formation. Gap formation results in microleakage. In this study Groups 1A, 2A, 3A, and 4A, whose gingival walls of the proximal boxes were located in enamel, showed less microleakage than Groups 1B, 2B, 3B, and 4B with the gingival walls of the proximal boxes located in dentin. There are several studies supporting the concept that marginal microleakage in enamel is less than in dentin.[14,18,22,23,30,31,32]

Future studies will be needed to focus on correlations between the gingival margin level and microleakage in actual oral conditions.

## Conclusion

Under the conditions of this *in vitro* study:

- Locations of the gingival margins 1 mm coronal to the CEJ showed lower microleakage than 1 mm apical to the CEJ for all composites tested.
- There were no significant differences for all composites tested in terms of interface, cervical, and occlusal voids.

## Clinical Significance

Gingival margin located in 1 mm coronal to the CEJ provided a reduction in cervical microleakage in nanocomposite restorations.

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