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Effect of Fiber Nets, Application Techniques and Flowable Composites on Microleakage and the Effect of Fiber Nets on Polymerization Shrinkage in Class II MOD Cavities

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Clinical Relevance

Fiber nets applied to Class II composite restorations resulted in a significant reduction in microleakage. Fiber nets also decreased polymerization shrinkage. Therefore, these materials may be acceptable for clinical applications. Incremental placement remains the preferred restorative technique for posterior composite restorations.

SUMMARY

This study evaluated the effects of fiber nets and application techniques and flowable composites as a liner on microleakage and the effects of fiber nets on polymerization shrinkage in Class II MOD cavities. Standard MOD cavities were performed in 80 extracted third molars. The teeth were randomly divided into eight groups (n=10). Group 1: Filtek Supreme XT (bulk technique) (FSB); Group 2: Filtek Supreme XT (incremental technique) (FSI); Group 3: Filtek Supreme XT Flow (FS Flow)+FSB; Group 4: FS Flow+FSI; Group 5: FS Flow+Ribbond (R)+FSB; Group 6: FS Flow+R+FSI; Group 7: FS Flow+everStick NET (E)+FSB; Group 8: FS Flow+(E)+FSI. All the teeth were then immersed in 0.5% basic fuchsin solution for 24 hours after thermocycling for 1000 cycles (5°C and 55°C). The teeth were sectioned longitudinally and observed under a stereomicroscope. In order to determine the polymerization shrinkage, another study was designed. In Group A, composite was applied as a bulk. In Group B, the resin composite was divided into two parts and Ribbond fiber was placed in the middle of the mass. In Group C, everStick NET fiber was placed inside the composite, as in Group B. Statistical analysis were performed by using one-way ANOVA and Tukey HSD tests for both microleakage and polymerization shrinkage ($p<0.05$). Less microleakage was observed in groups where composites were applied by the incremental technique compared with those

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DOI: 10.2341/08-57

where the bulk technique was used ($p<0.05$). The groups that used flowable composites showed significantly lower microleakage ($p<0.05$). In groups where fiber nets were used, a significant decrease was determined in terms of microleakage ($p<0.05$). Groups with fiber nets exhibited lower polymerization shrinkage ($p<0.05$). Fiber nets decreased both microleakage and polymerization shrinkage. The incremental technique is an effective method for Class II composite restorations.

INTRODUCTION

The use of resin-based composite materials for the restoration of posterior teeth has increased recently. This is not only a result of their advantages for esthetic properties, but also because of their increasing adhesion to dental tissues. Although resin-based composite materials have made significant improvements in their properties, composite restorations may still be unsuccessful clinically due to wear, inadequate polymerization and microleakage, which may also result in postoperative sensitivity and recurrent caries and/or possible loss of the restoration.[1-3]

Microleakage is one of the most frequently encountered problems for posterior composite restorations, in particular, at the gingival margins of Class II cavities.[4] It is well known that recurrent caries at the gingival margin of Class II restorations with resulting failure of the restoration has been attributed to such microleakage.[5] Some studies have reported efforts to develop methods to decrease this problem with Class II composite restorations.[6-7] These studies include methods for light polymerization proposed to reduce the amount of composite volumetric shrinkage, reducing C factor (the ratio of bonded to unbonded restoration surfaces) and following strategic incremental placement techniques in order to reduce residual stresses at the tooth/restoration interface.[6-7]

Recently, the use of flowable resin composites as liners in difficult areas of access has been suggested. This assumes that these less viscous materials flow easily onto all prepared surfaces, resulting in less leakage and postoperative sensitivity. Flowable resin composite liners may also act as a flexible intermediate layer that helps to relieve stresses during polymerization shrinkage of the restorative resin.[8]

The elastic modulus describes the relative stiffness of materials within their elastic range. A higher modulus of elasticity and lower flexural modulus of the polyethylene fiber was reported to have a modifying effect on the interfacial stresses developed along the etched enamel-resin boundary.[9] It has been found that, by embedding a Leno Weave Ultra High Modulus (LWUHM) polyethylene fiber into the bed of a flowable resin before composite restoration, higher microtensile bond strength could be achieved in prepared cavities with a high C-factor.[10] The C-factor affects dentin adhesion, but, by using an appropriate layering technique, bond strengths to deep cavity floors can be increased.[11]

Recently, glass fibers have also demonstrated their ability to withstand tensile stress and stop crack propagation in composite material.[12] When a glass fiber layer is applied, the internal stress patterns of the restorative material may change.[13] There is a major stress at the dentin/composite interface, and modifications that would reduce or eliminate the interfacial stress concentrations can reduce gap formation and microleakage.[14]

One of the major disadvantages of resin composites is polymerization shrinkage. Shrinkage occurs as resin composites polymerize, because monomers crosslink to form a polymer network that occupies a smaller volume than monomers.[15] A range of problems can result from this shrinkage, including gap formation at the restoration's margins, marginal staining, microleakage, postoperative sensitivity and recurrent caries.[16] Polymerization shrinkage can be reduced through limiting the degree of monomer conversion; however, this reduction will have adverse effects on the physical and mechanical properties of restorations. Maximum monomer conversion is always desired to ensure optimum properties and biocompatibility and reduce water solubility.[17]

This study investigated the effects of two fiber nets, application techniques (bulk and incremental) and flowable composites as a liner on the microleakage and the effect of fiber nets on polymerization shrinkage in Class II MOD cavities.

METHODS AND MATERIALS

Microleakage Test

The manufacturers and components of the materials utilized in this *in vitro* study are presented in Table 1. Eighty freshly extracted, impacted human third molars were used. Residual soft tissue was carefully removed and the teeth were stored with tymol crystals at 4°C in distilled water until use.

Standard MOD cavities were prepared in each tooth. These preparations were accomplished using diamond burs (Accurata, Germany) in a high-speed handpiece with water coolant. The 80 preparations were performed with the gingival margins placed on the cementoenamel junction (CEJ). New burs were used after every five preparations. All cavity dimensions were as follows:

- The dimensions of the occlusal portion of the cavity are 2 mm in both buccolingual width and depth. The dimensions of the burs utilized gauged all depths.

Table 1: *Manufacturers and Composition of the Materials Utilized in the Study*

Products	Type	Composition	Manufacturer
Adper Scotchbond Multi-Purpose	Total-etch adhesive system	Primer: HEMA Adhesive resin: HEMA, bis-GMA	3M ESPE, St Paul, MN, USA
Filtek Supreme XT	Nanofilled composite	zirconia/silica cluster, bis-GMA, UDMA, TEGDMA, bis-EMA	3M ESPE, St Paul, MN, USA
Filtek Supreme XT Flow	Nanofilled flowable composite	zirconia/silica cluster, bis-GMA, TEGDMA, bis-EMA	3M ESPE, St Paul MN, USA
Ribbond	Polyethylene fiber	Ultra-High molecular weight polyethylene	Ribbond Inc, Seattle, WA, USA
everStick NET	Glass fiber	E-glass (electric glass, silanated), bis-GMA and PMMA	Stick Tech, Turku, Finland

HEMA: 2-hydroxyethylmethacrylate
bis-GMA: bis-phenol A diglycidylmethacrylate
UDMA: urethane dimethacrylate
TEGDMA: triethyleneglycol dimethacrylate
bis-EMA: bis-phenol A polyethoxylated dimethacrylate
PMMA: polymethyl methacrylate

Table 2: *Study Design for Microleakage Test*

Groups	Application Procedure	Filling Technique
Group 1	Etching + Primer and Adhesive + Filtek Supreme XT	Bulk technique
Group 2	Etching + Primer and Adhesive + Filtek Supreme XT	Incremental technique
Group 3	Etching + Primer and Adhesive + Filtek Supreme XT Flow + Filtek Supreme XT	Bulk technique
Group 4	Etching + Primer and Adhesive + Filtek Supreme XT Flow + Filtek Supreme XT	Incremental technique
Group 5	Etching + Primer and Adhesive + Filtek Supreme XT Flow + Ribbond + Filtek Supreme XT	Bulk technique
Group 6	Etching + Primer and Adhesive + Filtek Supreme XT Flow + Ribbond + Filtek Supreme XT	Incremental technique
Group 7	Etching + Primer and Adhesive + Filtek Supreme XT Flow + everStick NET + Filtek Supreme XT	Bulk technique
Group 8	Etching + Primer and Adhesive + Filtek Supreme XT Flow + everStick NET + Filtek Supreme XT	Incremental technique

- The boxes were prepared 3.5-4 mm deep axially and the buccolingual width was 2 mm.
- The buccal and lingual walls of the preparations were approximately parallel and connected to the gingival wall with rounded line angles.
- The margins were not beveled.

The restorations were placed by a single operator according to the manufacturer's instructions. Per the manufacturer's instructions, each tooth was etched and the recommended bonding agent was applied and light cured. All the materials were cured using an LED light-curing unit (Elipar FreeLight 2, 3M ESPE, St Paul, MN, USA).

The 80 teeth were randomly assigned to eight groups of 10 teeth each. All the teeth were evaluated with both the mesial and distal side. Study design for the microleakage test is presented in Table 2. The application procedure is as follows:

Acid Etching Procedure

Thirty-seven percent Scotchbond Etchant (3M ESPE) was applied with a disposable brush (Microbrush, 3M Dental Products Division) for 15 seconds to the enamel of the prepared cavity. The etchant was rinsed off for 10 seconds with water from a triple syringe.

Primer and Adhesive Application Procedure

Adper Scotchbond Multi-Purpose primer (3M ESPE) was applied to the cavity and gently dried for five seconds. Adper Scotchbond Multi-Purpose adhesive (3M ESPE) was applied to the enamel and dentin, and the cavity was gently air dried for five seconds, leaving a shiny surface. The adhesive was then polymerized for 10 seconds.

Composite Application Procedure

Bulk Technique: A nanofilled composite, Filtek Supreme XT (3M ESPE), was placed into a cavity using a bulk technique. It was light cured from the mesial, occlusal and distal direction for 20 seconds, respectively.

Incremental Technique: Filtek Supreme XT was placed into the mesial cavity in a 2 mm thickness and cured for 20 seconds. It was then placed into the distal cavity in a 2 mm thickness and polymerized for 20 seconds. Finally, the resin composite was placed into the occlusal cavity in a 2 mm thickness and cured for 20 seconds.

Flowable Composite Application Procedure

A flowable composite (Filtek Supreme XT Flow, 3M ESPE) was placed and light cured for 20 seconds.

Fiber Net Application Procedure

Flowable composite was placed; however, 2 x 2 mm fiber nets (Ribbond THM, Ribbond and everStick NET, Stick Tech) were applied to the gingival and axial wall. Then, both flowable composite and fiber net were light cured together for 20 seconds.

All the composite restorations were finished and polished using fine burs (Accurata) and polishing disks (Sof-Lex, 3M ESPE). All the specimens were stored in distilled water at 37°C for 24 hours, they were then thermocycled for 1000 cycles between 5°C and 55°C (±2°C) with a dwell time of 15 seconds. The specimens were subsequently sealed with Filtek Supreme XT at the root apices. Two coats of nail varnish were applied onto the tooth 1.5 mm short of the margins to be exposed to dye. The teeth were then immersed in 0.5% basic fuchsin dye for 24 hours at 37°C. They subsequently were rinsed under running water to remove the dye. The specimens were sectioned longitudinally through the center of the restorations with a diamond saw (Isomet, Buehler, Ltd, Lake Bluff, IL, USA). The degree of dye penetration was graded by two examiners at 30x original magnification using a stereomicroscope (Leica MS5 Singapore, Singapore). The dye penetration scores are presented in Table 3.

Table 3: *Definition of Dye Penetration Scores*

Scores	Definitions
Score 0	No dye penetration
Score 1	Dye penetration less than 1/2 of the gingival wall
Score 2	Dye penetration along the gingival wall
Score 3	Dye penetration along the gingival wall and less than 1/2 of the axial wall
Score 4	Dye penetration along the gingival and axial wall

Polymerization Shrinkage Test

Measurement of the volumetric polymerization shrinkage was performed by using Acuvol (BISCO, Inc, Schaumburg, IL, USA). The specimens were prepared by dispensing approximately 10 µl of the resin composite (Filtek Supreme XT), manually shaping it into a semisphere and placing it on a sample stage. The stage was positioned so that the specimen's image appeared in the center of the display on the monitor. The specimen was allowed to rest for five minutes to eliminate the influence of slumping on the measurement and a two-dimensional visual image was captured by camera. The specimen's volume was measured and cured for 20 seconds using an LED light curing unit (Elipar FreeLight 2). The tip of the light source was positioned 1 mm from the top of the resin composite during light activation. The difference between the pre-cured and post-cured volume was used to calculate the percentage of volumetric shrinkage. Ten specimens from each group were tested. The study design for the polymerization shrinkage test is presented in Table 4.

Table 4: *Study Design for Polymerization Shrinkage Test*

Groups	n
Group A: Filtek Supreme XT	10
Group B: Filtek Supreme XT + Ribbond	10
Group C: Filtek Supreme XT + everStick NET	10

Group A: Only resin composite was used in this group.

Group B: The resin composite was divided into two parts and polyethylene fiber (Ribbond THM, Ribbond) was placed in the middle of the mass.

Group C: Glass fiber (everStick NET, Stick Tech) was placed inside the composite as in Group B.

Statistical Evaluation

Statistical analyses were performed by using one-way ANOVA and Tukey HSD tests for both microleakage and polymerization shrinkage at a significance level of $p<0.05$.

Table 5: *Distribution of Microleakage Scores Among the Test Groups*

Groups	Scores				
	0	1	2	3	4
Group 1	-	2	2	8	8
Group 2	1	4	8	6	1
Group 3	-	4	7	6	3
Group 4	-	5	9	4	2
Group 5	1	5	10	3	1
Group 6	4	6	8	2	-
Group 7	4	5	6	4	1
Group 8	4	7	6	3	-

Table 6: *Mean Values and Standard Deviations of Polymerization Shrinkage Test*

Groups	n	Mean Values and Standard Deviations (±)
Group A: Filtek Supreme XT	10	2.52 ± 0.03
Group B: Filtek Supreme XT + Ribbond	10	1.95 ± 0.06
Group C: Filtek Supreme XT + everStick NET	10	1.87 ± 0.04

RESULTS

The distribution of microleakage scores among the test groups is presented in Table 5. The mean values and standard deviations of the volumetric polymerization shrinkage test are exhibited in Table 6.

Marginal microleakage significantly decreased in groups where composites were applied by the incremental technique compared with those where the bulk technique was used ($p<0.05$). The fiber inserted groups had lower microleakage scores than the other groups ($p<0.05$). No significant difference was observed between the two different fiber materials that were tested ($p>0.05$).

When the groups were compared in terms of polymerization shrinkage, the fiber inserted groups showed lower volumetric shrinkage compared to Group A ($p<0.05$). However, there was no statistically significant difference between the two fibers in terms of polymerization shrinkage ($p>0.05$).

DISCUSSION

Marginal microleakage is one of the major disadvantages of resin composite restorations. Failure of the material to adapt to dentin structure causes microleakage, generally at the gingival margin. Once a layer of resin composite is inserted into the cavity and is light cured, a competition between polymerization shrinkage of the composite and adhesion to the substrate begins. Stresses produced by polymerization shrinkage are critical to adhesion between the resin composite and the tooth structure.[18-19] This shrinkage stress depends on factors, such as cavity size and shape, substrate type and location of the margins, restorative material and the technique of placement and polymerization. If bond strength is weaker than shrinkage stresses between the resin and adhesive system, the tooth-restoration interface may break, forming a gap that will allow for marginal microleakage.[20]

Xu and others[21] stated that, when fiber inserts are placed in Class II composite restorations, they increase the quality of the marginal zone in two ways. First, the fibers replace the part of the composite increment at this location, which results in a decrease in the overall volumetric polymerization contraction of the composite. Second, the fibers assist the initial increment of the composite in resisting pull-away from the margins toward the light source. The fibers also may have a strengthening effect on the composite margin, which may increase resistance to dimensional change or deformation that occurs during thermal and mechanical loading and, thus, improves marginal adaptation.[21] In the current study, both polyethylene and glass fibers decreased the marginal microleakage of the resin composites. El-Mowafy and others[7] found the same results, and their study also supported the findings of the current study.

Kolbeck and others[22] reported that the reinforcing effect of glass fibers was more effective than polyethylene fibers. This finding was attributed to the difficulty in obtaining good adhesion between the polyethylene fibers and resin matrix. However, Hamza and others[23] found no significant difference between the reinforcing effects of glass and polyethylene fibers. This may explain the similarity in microleakage scores between groups restored with the two types of fiber inserts. Studies by both Kolbeck and others[22] and Hamza and others[23] supported the results of the current study, where glass fibers, when compared with polyethylene fibers, showed less microleakage scores, but there was no statistically significant difference between the glass and polyethylene fibers.

To reduce marginal leakage, flowable composites were recommended by the manufacturers.[24] Flowable composites used as a liner under high filled resins in posterior restorations have been shown to improve the adaptation of composites and effectively achieve clinically acceptable results.[25] It was stated that, applying flowable composites caused the greatest reduction in microleakage.[26] Used in Class II restorations, flowable composite is considered an easily handled, time-saving material.[27] Flowable composite has better mechanical strength and radio opacity and it does not require an additional dentin treatment. Flowable composite is considered to have potential uses for other clinical dental applications.[28] Low elasticity modulus of flowable composites provides flexibility for the bonded restoration.[29] Lining might lead to a more equal distribution of stresses over the adhesive interface and reacts as a stress breaker.[30-31] In the current study, flowable composite application reduced microleakeage.

In order to reduce contraction stresses, the incremental technique has been advocated for placement of the composite.[32] In the current study, both incremental and bulk techniques were compared, and it was found that applying the resin composite in increments reduces microleakage. Several studies, which were parallel to the current findings, were reported.[33-36]

Recently, variations in curing light devices have become available for the polymerization of light-cured dental materials. Halogen light-curing units are the most commonly utilized light sources. LED technology may overcome some of the problems of halogen light curing units; therefore, this technology has widespread usage in dentistry.[37] In the current study, all polymerization procedures were performed by LED light-curing units.

The dye penetration method is frequently used in order to measure microleakage. All the teeth were immersed in 0.5% aqueous basic fuchsin dye for 24

hours at 37°C. Aqueous basic fuchsin dye provides a simple, relatively inexpensive quantitative and comparable method of evaluating the leakage of resin composite.[38]

In the current study, the finishing and polishing procedures of the restorations were performed by fine burs and Sof-Lex discs. In order to standardize the procedures, the effect of polishing on all microleakage restorations was finished and polished in a similar manner.

Resin-based composites are usually utilized for posterior restorations. However, they undergo a volumetric polymerization contraction of at least 2.0%, which may result in gap formation as the resin composite pulls away from the cavity margins during polymerization.[6,18] This gap may cause fracture, forming a crack, favoring the marginal microleakage, which allows for the passage of bacteria, fluids, molecules or ions between the cavity surfaces and the restorative material, resulting in failure of the restorative techniques.[39]

Polymerization shrinkage is an inherent property of resin composites. Monomer conversion into polymer results in a closer, tighter arrangement of molecules, leading to a reduction in material volume.[17] Intermolecular distance changes from 0.3-0.4 nm to 0.15 nm on the polymerization of resin composites.[40]

If the total amount of composite material used to restore a Class II cavity could be reduced, the overall amount of polymerization shrinkage would be proportionately decreased.[7] In the current study, the fibers-inserted groups (Groups B and C) exhibited lower polymerization shrinkage. Ribbond and everStick NET separately exhibited significant differences compared with Group A, which has no fiber material. This result may explain that, when fiber nets are inserted into the resin composite, the composite mass may decrease. Less resin composite mass means less volumetric shrinkage, because of the presence of less organic matrix. Therefore, the authors of the current study may recommend fiber applications in Class II restorations in terms of reducing polymerization shrinkage.

CONCLUSIONS

Under the conditions of the current *in vitro* study:

1) Microleakage significantly decreased in groups where composites were applied by the incremental technique compared with those where the bulk technique was used.
2) Groups where flowable composites were used as a liner exhibited lower microleakage than the other groups.
3) In groups where fiber nets were used, a significant decrease was determined in terms of microleakage.
4) Groups with fiber nets caused a decrease in polymerization shrinkage.

(Received 15 April 2008)

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