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The Effect of Flowable Materials on the Microleakage of Class II Composite Restorations That Extend Apical to the Cemento-enamel Junction

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Clinical Relevance

The use of a flowable resin composite or compomer may reduce microleakage at the gingival floor of a deep Class II composite restoration that extends apical to the cemento-enamel junction.

SUMMARY

This *in vitro* study investigated the effects of a thin layer of flowable composite or compomer on microleakage occurring in Class II packable and nanofilled composite restorations that extend apical to the cemento-enamel junction (CEJ). The current study also investigated any differences in microleakage that occur between restorations light-cured using a light-emitting diode (LED) and a quartz tungsten halogen (QTH) light-curing unit. Standardized Class II "slot" cavity preparations were prepared on the mesial and distal surfaces of 72 extracted, unrestored, non-carious premolars (n=144). The gingival margins were placed 1 mm apical to the CEJ. The teeth were divided into two groups (n=72) and restored with a "packable composite" (Filtek P60) or a "nano-filled composite" (Universal Filtek Supreme XT) with or without flowable composite (Flowable Filtek Supreme XT) or flowable composite (Dyract Flow) as gingival liners placed with thicknesses of 1.0 mm. Each increment was cured for 20 seconds before adding the next. One-half of the samples in each group was cured with QTH (Coltolux 75) and the other half with LED (Coltolux LED) LCUs. After a two-week incubation period at 37°C, the specimens were thermocycled (5°C-55°C x 1500), immersed in 0.5% basic fuchsin dye for 24 hours, sectioned and the microleakage was then evaluated at the gingival margin by two examiners using a 0-3 score scale. Within the current study, when flowable liners were used, both the pack-

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able (Filtek P60) and nanofilled (Filtek Supreme XT Universal Restorative) composite materials had significantly less microleakage than when flowable liners were not used (*p*<0.05). Both flowable liners (Flowable Filtek Supreme XT and Dyract Flow) resulted in a significant reduction of the microleakage occurring under both types of composite materials at the gingival floors (*p*<0.05), but there was no significant difference between them. The choice of light curing technology (LED vs QTH) had no significant effect on the amount of microleakage observed.

INTRODUCTION

The placement of resin composites in posterior teeth has increased in popularity in recent years, driven by factors such as their increasing predictability and esthetic demands from patients.[1] While Class II composite restorations can be placed at an acceptable standard if the gingival margin is in sound enamel, there has been much debate regarding the marginal integrity of composite restorations that extend apical to the cementoenamel junction (CEJ).[2] Furthermore, difficulty in obtaining adaptation of the composite material to the internal surfaces of the cavity and achieving a proper marginal seal may result in post-operative sensitivity.[3-4]

Packable composites claim to eliminate some of these difficulties. These materials feature increased filler loading, which gives them a different consistency compared with hybrid restorative composites. They are recommended for use in stress-bearing posterior regions and offer improved handling properties, such as increased sculptability and handling characteristics similar to amalgam restorations.[1-3] Nanofilled composites are a recently developed composite material featuring significantly smaller filler particles than those in conventional hybrid composites. They offer high translucency, high polish and superior polish retention.[5-6] Clinically, nanofilled composites exhibit sufficient compressive strength and wear resistance to justify their use in high stress–bearing areas, such as the occlusal surfaces of posterior teeth.[5] Nanofilled resins feature approximately 60% volume filler loading, making their physical properties comparable to those of hybrid and microhybrid resins.[7]

Certain clinical problems, such as the presence of marginal gaps and post-treatment sensitivity, can be encountered with Class II composite restorations. To reduce these effects, flowable composites have been recommended as liners at the cementum margins of the proximal box of Class II resin composite restorations to improve marginal integrity,[3,8] with the hope of reducing microleakage and post-operative sensitivity.[9] Flowable compomers are polyacid-modified resin composites that possess the characteristics of both flowable composites and glass ionomers, and they claim to improve the adhesive properties of conventional glass ionomer cements (GICs), while incorporating other favorable aspects of GIC chemistry, such as fluoride release. These materials are also advocated for use as stress-relieving gingival increments in Class II composite restorations, such as flowable composites.[10-11]

For nearly two decades, conventional quartz tungsten halogen (QTH) light curing units (LCUs) have been used to polymerize resin composites.[12] The advantage of QTH LCUs is that they are relatively inexpensive to produce.[13] However, these lights have a number of inherent limitations, such as degradation of the bulb, filter, reflector and a limited effective lifetime. Moreover, resin composite is not likely to be completely polymerized with an aged LCU. The reduction of light intensity due to long usage of the LCU is well known. More recently, the use of light-emitting diode (LED) LCUs that produce blue light have been described for the polymerization of resin composite and other light-activated dental materials. LED LCUs are lightweight, portable, have ergonomic handling capabilities, are highly efficient and have long life spans. Since a narrow band of light is emitted, there is no need for filter systems. LED LCUs have low amounts of wasted energy and reduced heat generation, which removes the need for including cooling fans. As the power consumption of LED LCUs is low, they can be powered by batteries. Other advantages include a consistent light output, no bulb to change and a long service life.[13-16]

The current *in vitro* study investigated the effect of a thin layer of flowable composite or compomer on microleakage in Class II packable and nanofilled composite restorations that extend apical to the cementoenamel junction and it investigated any differences in microleakage occurring between restorations that were light-cured using a light-emitting diode (LED) or a quartz tungsten halogen (QTH) light curing unit.

METHODS AND MATERIALS

Seventy-two unrestored, non-carious maxillary first premolars recently extracted for orthodontic reasons were selected. After cleaning with pumice slurry water, the teeth were stored in saline at room temperature for less than three months. They were then stored in an aqueous buffered solution of formaldehyde (Yekta Chem Co, Tehran, Iran) for two hours for infection control. Mesio-occlusal and disto-occlusal Class II "slot" cavity preparations were made in each tooth using a #836R cylinder diamond bur (Diatech Dental AG, Heerbrugg, Switzerland) with a head diameter of 1 mm and a head length of 6 mm in a high-speed handpiece with water-cooling. A new bur was used for every five preparations.

The slot cavity preparations were separated with sound tooth structure. The buccolingual width was 2.5 mm, and the gingival margins of all the cavities were placed 1 mm apical to the CEJ. The buccal and lingual walls of the preparations were approximately parallel and connected to the gingival floor with rounded line angles. The boxes were prepared 1.5 mm deep axially and the margins were not beveled (90° cavosurface angle) but were smoothed with a #23 hatchet (Duflex, SS White, Rio de Janerio, RJ, Brazil). In order to simulate clinical posterior teeth alignment, the premolars were mounted in stone jigs with a canine tooth on the mesial side and a second premolar on the distal side. A matrix retainer (Tofflemire, KerrHawe SA, Bioggio, Switzerland) and a metal band (Tofflemire, KerrHawe SA) were placed on the tooth and tightly held by two wooden wedges (Hawe-Neos Dental, Bioggio, Switzerland). A sharp explorer was used to confirm the accuracy of fit between the metal matrix and the cervical margin. The cavity preparations were placed by a single operator and restored according to the manufacturer's instructions.

All preparations in each group were rinsed with water, etched with 37% phosphoric acid etching gel (3M ESPE, St Paul, MN, USA) for 15 seconds, rinsed with a water jet for 20 seconds and gently air dried, leaving the surfaces wet. The bonding agent was Single Bond (3M ESPE), which was applied according to the manufacturer's instruction. The prepared teeth were randomly divided into two groups according to the resin composite used to restore the teeth; each group was subdivided into six groups for two flowable materials and two LCUs (n=12) (Figure 1). The LCUs selected for the current study included a QTH (Coltolux 75, Coltene/Whaledent Inc, Cuyahoga Falls, OH, USA) and an LED (Coltolux LED, Coltene/Whaledent Inc). Exposure times for the bonding agent (Single Bond, 3M ESPE) and each increment of the resin composites were 20 seconds for two LCUs.

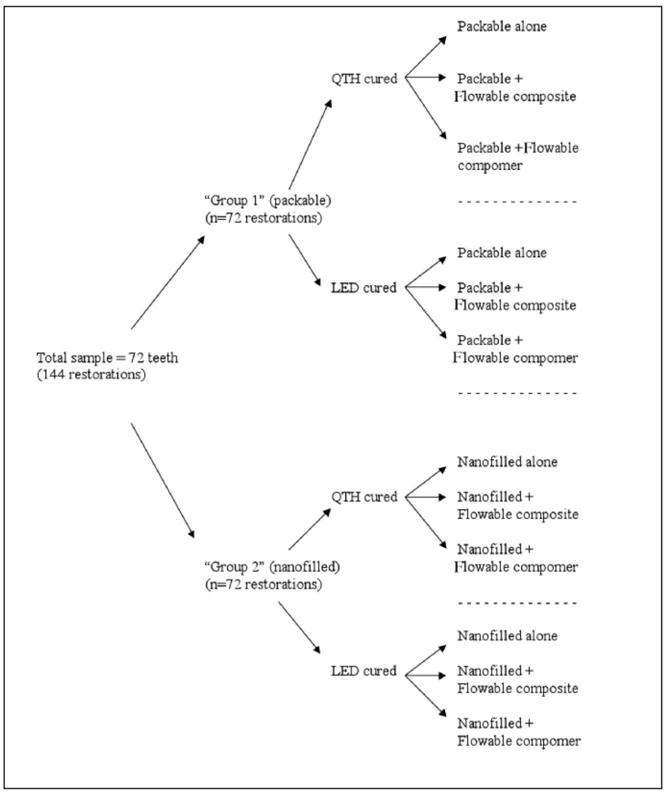

Figure 1. *Experimental design used in this study.*

The experimental design is described diagrammatically in Figure 1. The materials used were:

- "packable" composite = Filtek P60 (3M ESPE);
- "nanofilled" composite = Universal Filtek Supreme XT (3M ESPE);
- "flowable" composite = Flowable Filtek Supreme XT (3M ESPE);
- "flowable" compomer = Dyract Flow (Dentsply, DeTrey, GmbH, Konstanz, Germany).

The flowable materials were each injected onto the gingival floor of the cavity to a thickness of 1 mm; this depth was judged by a periodontal probe (Hu-Friedy Mfg Co, Inc, Chicago, IL, USA). A horizontal incremental technique with three increments from the cervical to the occlusal surfaces was used to restore the cavities. A 20-second curing time was used for two LCUs from the occlusal aspect in each layer according to the composite manufacturers' recommendations. (While the effects of the subsequent irradiation on a polymerized composite are regarded as negligible, an effort was made to "protect" the completed restorations on one aspect of the tooth, while the other aspect was being light cured. To achieve this, a layer of shimstock foil [Shimstock Foil, Prestige Dental, Yorkshire, UK] was pressed against the occlusal surface of the completed restoration, while the other surface was light cured). Following the restoration procedure, the metallic matrix was removed, the restoration was light cured for 20 seconds from the buccal and lingual surfaces and the occlusal surface was finished and polished. The specimens were removed from the stone mounting jigs, washed under running tap water for two minutes, stored in distilled water at 37°C for two weeks, then thermocycled for 1500 cycles between 5°C and 55°C at a dwell time of 30 seconds. Prior to the microleakage test, the apices of the samples were sealed with utility wax. The tooth was painted with two coats of fingernail varnish except for the restoration and 1 mm beyond the margins and allowed to air dry. It was then immersed in a 0.5% basic fuchsin dye (Merck KGaA, 64271 Darmstadt, Germany) for 24 hours.

After removal from the dye, the samples were cleaned under running tap water for two minutes and sectioned mesiodistally through the center of the restorations with a water-cooled diamond disk (Diamant, Horico, Berlin, Germany) to obtain two sections from each tooth. The sections were randomly arranged and assigned code numbers to permit blind evaluation. Dye penetration was examined (both surfaces) at the gingival margins using a stereomicroscope (Olympus Optical Co, Tokyo, Japan) under 10x magnification by two independent pre-calibrated examiners and consensus was forced when disagreements occurred. The examiners were blind to the materials and techniques. The following scoring criteria were used to evaluate the microleakage:

- score 0 = no dye penetration
- score 1 = dye penetration less than 1/3 of the gingival floor
- score 2 = dye penetration beyond 1/3 of the gingival floor, up to the axial wall
- score 3 = dye penetration along the axial wall[17]

The data were statistically analyzed by the Kruskal-Wallis and Mann-Whitney U-test at a significant level of 0.05.

RESULTS

None of the groups showed complete prevention of dye penetration. Table 1 shows the number of teeth in each microleakage-rating category. The packable (Filtek P60) and nanofilled (Filtek Supreme XT Universal Restorative) with flowable liners had significantly less microleakage than those without ($p<0.05$). When comparing each group individually, there was no significant difference between utilizing the flowable composite (Flowable Filtek Supreme XT) or flowable compomer (Dyract Flow). No significant difference in microleakage was identified between each comparable group when polymerized with either the LED (Coltolux LED) or QTH (Coltolux 75) LCUs individually.

DISCUSSION

The current *in vitro* study has presented some interesting findings when managing the difficult clinical scenario of the "deep" Class II composite restoration that extends apical to the cemento-enamel junction, and whose gingival cavosurface margin finishes on cementum, not enamel.

In the current study, the use of a flowable gingival liner under both the packable and nanohybrid composite materials resulted in a reduction in the amount of microleakage that occurred ($p<0.05$). There was also less microleakage observed under packable composites placed without a flowable liner when compared with nanohybrid materials placed without a flowable liner ($p<0.05$), and less microleakage observed under packable composites when a flowable liner was used when compared with nanohybrid materials placed with a flowable liner ($p<0.05$). Consequently, the effect of the physical properties of the packable material cannot be discounted. This confirms an effect observed in a previous study by Loguercio and others.[19] Packable composites feature increased filler loading in comparison with nanohybrid materials. The fillers of Filtek P60 are in the form of irregular, rounded, colloidal silica and zirconia/silica particles, 61% filled by volume with a particle size range of 0.1-3.5 µm.[1] Such increased filler/resin ratio and particle size within a composite material reduces the amount of polymerization contraction, which may result in decreased amounts of microleakage observed. On a more practical note, since packable

Table 1: *The Microleakage Scores and Mean ± SD of Tested Groups in Gingival Floor (n=12 per subgroup)*

Restorative Materials Groups	Microleakage Scores*				Mean ± SD
	0	1	2	3	
Packable + QTH	2	3	5	2	1.58 ± 0.97
Packable + LED	1	5	5	1	1.50 ± 0.80
Packable + Flowable composite + QTH	5	4	3	0	0.83 ± 0.83
Packable + Flowable composite + LED	4	5	1	2	1.08 ± 1.08
Packable + Flowable compomer + QTH	5	4	2	1	0.92 ± 1.00
Packable + Flowable compomer + LED	4	4	4	0	1.00 ± 0.85
Nanofilled + QTH	1	3	4	4	1.92 ± 1.00
Nanofilled + LED	1	4	4	3	1.75 ± 0.97
Nanofilled + Flowable composite + QTH	3	4	3	2	1.33 ± 1.07
Nanofilled + Flowable composite + LED	2	5	4	1	1.33 ± 0.89
Nanofilled + Flowable compomer + QTH	3	3	5	1	1.33 ± 0.98
Nanofilled + Flowable compomer + LED	2	4	5	1	1.42 ± 0.90

**Legend:*
Score 0 = no dye penetration
Score 1 = dye penetration less than 1/3 of the gingival floor
Score 2 = dye penetration beyond 1/3 of the gingival floor, up to the axial wall
Score 3 = dye penetration along the axial wall

composites are more viscous and less sticky than traditional resin composites, there may be less displacement and better adaptation of the material to the cavity walls during placement—again decreasing the potential for marginal void formation and possible microleakage.[8,17-18]

In the current study, the use of both flowable liners (Flowable Filtek Supreme XT and Dyract Flow) significantly reduced microleakage in two composite restorations at the gingival floors ($p<0.05$); but there was no significant difference between them. Composites have a relatively high modulus of elasticity, and employing an intermediate layer[10-11] of flowable composite or compomer liner may provide better adaptation. Due to their relative flexibility, these liners help relieve stresses during polymerization shrinkage of the composite restorations.[1,8,10,18] (This is a different mechanism to that postulated for the packable materials above, where an increase in filler size and content and the associated reduction in volume of the resin phase resulted in a reduction in polymerization contraction). Neme and others[8] concluded that placement of a flowable compomer as a liner beneath its packable counterpart had resulted in the least amount of overall leakage compared with the other material combinations, where a flowable composite was used as a liner. The use of flowable materials as a liner underneath the resin composites may reduce the effects of the C-factor (the C-factor being the ratio of bonded to unbonded surfaces linked by an increment of composite being cured; increments linking fewer surfaces are regarded as having a reduced "C-factor," in turn, leading to a reduction in polymerization stress and associated problems). Lowering the C-factor may lower the internal stresses within the placed restoration.[5,12] However, the benefit of the gingival liner for reducing polymerization contraction stress is still somewhat controversial.[1,9] *In vitro* studies have reported significant effects of using flowable composite or compomer as gingival increments in reducing the microleakage of Class II composite restorations.[4,10,17,19,20-22] In contrast, other studies have reported that the use of flowable materials as intermediate material do not reduce microleakage in Class II composite restorations with margins placed in cementum/dentin.[8,23-24] The current study confirms the former, particularly when cavity margins extend apical to the cemento-enamel junction.

The second aim of the current study was to compare the efficacy of LED and QTH LCUs. No significant differences in microleakage were identified between the restorations polymerized with LED compared with QTH LCUs. This is comparable to the results of a similar study published by Fleming and others,[15] who reported that no significant difference in microleakage was identified between Z100 (3M ESPE) and Filtek Z250 (3M ESPE) when polymerized with either LED or QTH LCU. However, in the study by Fleming and others, cavities restored with P60 (3M ESPE) exhibited significantly increased microleakage when polymerized using the LED compared with QTH LCU.[15] They found that such an observation was caused by the high energy output from the LED LCU used in their study, which they felt could potentially disrupt the early polymerization kinetics within the P60 brand composite material.[15] This effect has also been observed/commented on when certain high-powered LED LCUs are used to polymerize certain brands of composite material.[25] Second-generation LED LCUs (as used in the current study) have been demonstrated to be as effective or more effective than a QTH LCU for polymerization of composites.[26-28] In the current study, the authors demonstrated that microleakage occurring under the different materials and combinations of liners and materials was not affected by the choice of LCU.

CONCLUSIONS

Within the limitations of the current *in vitro* study, it can be concluded that the use of flowable composite (Flowable Filtek Supreme XT) or flowable compomer (Dyract Flow) as a gingival liner in Class II packable (Filtek P60) and nanofilled (Universal Filtek Supreme XT) composite restorations decreases gingival microleakage. The packable composite had significantly less microleakage than the nanofilled composite with and without flowable liners. The restored teeth that were polymerized with LED LCUs showed similar microleakage scores compared with QTH LCUs. However, further *in vitro* and *in vivo* investigations are needed to determine the clinical validity of these techniques.

Declaration

The authors have no interest, financial or otherwise, in the products included in this study.

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