Microleakage around Glass-Ceramic Insert Restorations Luted with a High-Viscous or Flowable Composite

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ABSTRACT

Purpose: The purpose of this study was to evaluate microleakage around Class V resin restorations restored with glass-ceramic inserts luted with a high-viscous composite resin or a flowable composite resin.

Materials and Methods: Twenty extracted human premolars (patient age range 12–18 yr) were randomly assigned to four groups. Class V preparations in two groups were filled using a glass-ceramic insert (Megafiller Standardformen, Hager Werken GmbH, Duisburg, Germany) luted with either a hybrid, high-viscous composite (Tetric, Ivoclar Vivadent, Schaan, Liechtenstein) and a bonding agent (Excite, Ivoclar Vivadent) or a flowable composite (Crystal-Essence, Confi-Dental, Louisville, CO, USA) and a bonding agent (Confi-Quick, Confi-Dental). Two groups without inserts served as controls and were bulk filled with either a hybrid, high-viscous composite (Tetric) or a flowable composite (Crystal-Essence). The preparations were made with a no. 330 tungsten carbide fissure bur (Komet, Lemgo, Germany) in a water-cooled, high-speed handpiece with a mesiodistal width of 3 mm, an occlusogingival height of 3 mm, and a depth of 2 mm. All margins had butt joints. The teeth were thermocycled for 24 hours in water baths held at 5°C and 55°C, and the specimens were prepared and examined for microleakage using basic fuchsin as a marker. Relative leakage was recorded according to the extent of dye penetration on a scale of 0 to 4, with 0 indicating no dye penetration and 4 indicating that dye penetration had progressed as far as the cavity floor. The results were analyzed using the Kruskal-Wallis test (nonparametric analysis of variance) and Dunn's multiple comparisons test ($p < .05$).

Results: There was no significant difference in microleakage around inserts luted with a high-viscous composite occlusally ($p = .7563$) or gingivally ($p = .6187$) and around cavities bulk filled with the high-viscous composite. There was a significant difference in microleakage around inserts luted with a flowable composite both occlusally ($p = .0345$) and gingivally ($p = .0285$) and around cavities bulk filled with the flowable composite. Inserts luted with the flowable composite showed significantly less microleakage than those cemented with the high-viscous material only at the gingival margins ($p = .0345$). Comparisons of microleakage around the high-viscous and flowable composites showed no significant difference in microleakage at either the occlusal or gingival margins (Dunn's multiple comparisons test $p > .5$ in all cases).

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CLINICAL SIGNIFICANCE

In Class V preparations of the size cut in the present study, ceramic inserts are shown to be of value in reducing microleakage when compared with bulk filling with flowable composites. Microleakage was not significantly improved by using a ceramic insert with a viscous composite compared with the viscous composite alone.

(*J Esthet Restor Dent* 17:30–39, 2005)

Modern insert systems have been available since their introduction by Bowen and colleagues.[1] With the increasing demand for an alternative to amalgam and patients' desire for tooth-colored, cost-effective restorations, there has been an increased interest in this type of system.

The major disadvantages associated with conventional composite restorations are polymerization shrinkage and associated contraction stresses. When the contraction stresses exceed the adhesive force of the composite to the tooth substrate, marginal gap formation and microleakage occur.[2] Composite shrinkage stress is influenced by many factors, including cavity size and configuration,[3] type of composite, and light intensity.[4] An incremental placement technique is claimed to reduce shrinkage stress,[5] but there are conflicting reports regarding the efficacy of this method.[6–10]

Reducing the volume of resin by adding inorganic filler material achieves a reduction in polymerization shrinkage, and some manufacturers have increased the filler content of their composites to as much as 75% by volume.[11] However, the working properties of a composite are adversely affected by an increased filler-resin ratio, which militates against high filler volume. According to Bowen and colleagues,[1] inserts act as "megafillers" that allow a reduction in resin-based composite volume by 50 to 75%, with a concomitant reduction in polymerization shrinkage and marginal microleakage.[12] Moreover, the integration of ceramic inserts into composites reduces the overall coefficient of thermal expansion, which has been shown to reduce contraction and expansion under thermomechanical stress.[13]

Glass-ceramic inserts are made from stabilized lithium aluminosilicate glass combined with various modified oxides, and they undergo a heat treatment to give the material a toothlike appearance.[14] They are usually surface treated with silane to improve bonding characteristics.[15]

Several reports indicate that the use of a glass-ceramic insert reduces marginal gaps between the cavity wall and the composite material,[16,17] as well as microleakage around Class II and Class V cavities.[18–20] Others have indicated that in Class V cavities, the use of a ceramic insert is no better than a bulk insertion technique.[21]

Manufacturers of prefabricated ceramic inserts tend to recommend the use of a highly filled, fine-particled or high-viscous composite in conjunction with the insert.[22,23] Interestingly, a recent study showed that microleakage around Class II cavities restored with either ceramic inserts or composite alone was not found to be significantly different, and that the main factors influencing the outcome were considered to be the choice of bonding agent and/or the pretreatment procedures.[24] Marginal adaptation has been enhanced when ceramic inserts were seated with minimal luting agent,[13] and the stiffness of luting materials has been an important parameter in reducing marginal microleakage of ceramic inlay restorations.[25]

The purpose of the present study was to evaluate the effect of restorations involving a glass-ceramic insert (Megafiller Standardformen, Hager Werken GmbH, Duisburg, Germany) in conjunction with a microfilled, high-viscous hybrid composite (Tetric, Ivoclar Vivadent, Schaan, Liechtenstein) or a flowable composite (Crystal-Essence, Confi-Dental, Louisville, CO, USA) on microleakage around Class V cavities. Class V cavities bulk filled with the high-viscous composite alone or the flowable composite alone were used as controls.

MATERIALS AND METHODS

Twenty noncarious, permanent premolars (patient age range 12–18 yr) that had been extracted during the provision of routine orthodontic treatment and that had been stored for < 4 months in 0.2% thymol solution were used in this study. Immediately after extraction, the teeth were scaled to remove any calculus and polished with pumice and rubber cups to remove plaque and debris.

Following International Standards Organization (ISO) guidelines,[26] a standardized Class V preparation was made on the buccal and lingual aspects of each tooth. Preparation size was standardized using a template to trace an outline on both buccal and lingual surfaces with a mesiodistal width of 3 mm and an occlusogingival height of 3 mm. The depth of the preparation was 2 mm and was calibrated by measuring with a premarked periodontal probe. Preparations were cut using a tungsten carbide fissure bur no. 330 (Komet, Lemgo, Germany) in a high-speed handpiece and a copious water spray. The cavosurfaces were finished with a no. 53 stainless steel fissure bur (Komet) in a low-speed handpiece. The gingival margin was 1 mm occlusal to the cemento-enamel junction, and all margins were prepared with a butt joint.

The teeth were randomly assigned to four groups (n = 5) according to the type of composite used as a luting agent and whether an insert was used. The materials used, their composition as given by the manufacturer, their batch number, and some relevant physical properties are listed in Table 1. In all four groups, the bonding agents and composites were cured using a light-curing unit (Astralis 10, Ivoclar Vivadent). The intensity of the light-curing unit was monitored by a Demetron Radiometer (Demetron Kerr, Danbury, CT, USA) and was always in excess of 500 mW/cm^2.

In groups 1 and 2 (see below for description), immediately after curing, the insert handle was cut off and the restoration was shaped with a medium-grit diamond bur in a high-speed handpiece with a copious water spray.

All twenty samples were polished dry with Sof-Lex disks (3M ESPE, St. Paul, MN, USA) immediately after the composite was cured, finishing with a fine grit. The samples were then stored in deionized water for 24 hours at 37°C.

A total-etch technique was used for all four groups, and the materials were placed strictly according to the manufacturers' instructions.

Group 1: Glass-Ceramic Insert, Tetric Composite, Excite Dentin Bonding Agent

Using a disposable brush, 37% phosphoric acid gel (TotalEtch, Ivoclar Vivadent) was applied to the enamel and dentin of group 1 specimens for 15 seconds. The etchant was rinsed from the cavity for 15 seconds and the cavity dried with oil-free air from a dental syringe. Care was taken not to dehydrate the tooth surfaces. Excite bonding agent (Ivoclar Vivadent) was applied with a disposable brush to thoroughly wet all tooth surfaces and was left undisturbed for 20 seconds. Excessive solvent was removed with a blast of air from a syringe lasting not more than 5 seconds, and the remaining material was cured for 20 seconds. Immediately, a Tetric composite restoration was placed over the cured bonding material and a glass-ceramic insert, 2.0 mm in diameter and 2.0 mm long, was pressed into the composite at the center of the restoration until firmly seated. The insert was at all times held in endodontic locking tweezers, and care was taken not to touch or contaminate the pre-silanated surface. After seating, excess composite was removed and the remaining composite was adapted around the insert and against the preparation

TABLE 1. MANUFACTURERS, BATCH NUMBERS, AND PHYSICAL PROPERTIES OF MATERIALS USED.

Product	Manufacturer	Batch No.	Physical Properties*
Glass-ceramic insert	Hager Werken GmbH	0219922	Formed from lithium aluminosilicate glass, phase separated by heating to specific temperatures and water quenched to form microcrystalline ceramic. Inserts are silane treated for additional chemical bond to composite resin. Coefficient of thermal expansion 3–4 ppm
Tetric	Ivoclar Vivadent	C41011	Monomer matrix contents: dimethacrylate, urethane dimethacrylate, triethylene glycol dimethacrylate 18.8 wt% Inorganic fillers: barium glass, ytterbium trifluoride, highly dispersed silicon dioxide, spheroid mixed oxide 81.0 wt% Catalysts: stabilizers, pigments 0.2 wt% Total inorganic filler content 81% by weight Mean particle size 0.7 μm Coefficient of thermal expansion 26 ppm
Crystal-Essence	Confi-Dental	E7019	Silanated barium glass 53–63% Bisphenol 'A' diglycidyl methacrylate 13–17% Ethoxylated bisphenol 'A' dimethacrylate 9–12% 1,6 hexanediol dimethacrylate 3–7% Fumed silica 4–7% Titanium dioxide <1% Sodium fluoride 1.5–2.5% Tertiary amine <5% Benzophenone <0.5% Triethylene glycol dimethacrylate 3–6% a-diketone <2% Iron oxide (dye) <1% Total inorganic filler content 64% by weight Mean particle size 0.7 μm Coefficient of thermal expansion ~38 ppm
Excite	Ivoclar Vivadent	C39451	Phosphoric acid acrylate Hydroxyethyl methacrylate Dimethacrylate 73.6% Highly dispersed silica 0.5% Ethanol 25.0% Catalysts and stabilizers 0.9% Particle size not given
Confi-Quick	Confi-Dental	E6245	2-hydroxyethyl methacrylate <20% 1,4-dimethacryloyloxyethyl pyromellitate acid 30–35% Acetone base

*Information is from manufacturers.

walls. The insert-composite restoration was cured for 40 seconds.

Group 2: Glass-Ceramic Insert, Crystal-Essence Composite, Confi-Quick Dentin Bonding Agent
Using a disposable brush, 37% phosphoric acid gel (Confi-Quick Etchant, Confi-Dental) was applied to the enamel and dentin of specimens in group 2 for 15 seconds. The etchant was rinsed from the preparation for 10 seconds, and the preparation was dried with oil-free air from a dental syringe for 2 seconds. Care was taken not to dehydrate the tooth surfaces. Confi-Quick adhesive was applied with a disposable brush to thoroughly wet all tooth surfaces and left undisturbed for 10 seconds. Excessive solvent was removed with a blast of air from a syringe lasting not more than 5 seconds, and the remaining material was cured for 20 seconds.

Immediately, a Crystal-Essence composite restoration was placed over the cured bonding material, and a glass-ceramic insert, 2.0 mm in diameter and 2.0 mm long, was pressed into the composite at the center of the restoration until firmly seated. The insert was at all times held in endodontic locking tweezers, and care was taken not to touch or contaminate the pre-silanated surface. After seating, excess composite was removed and the remaining composite was adapted around the insert and against the preparation walls. The insert-composite restoration was cured for 40 seconds.

Group 3 (Control A): Tetric Composite, Excite Dentin Bonding Agent
The procedures used for specimens in group 3 were the same as those described for group 1, except that a bulk-filled Tetric composite restoration was immediately placed over the cured adhesive. The composite was covered with a cellulose strip to counteract the effect of oxygen inhibition and was cured for 40 seconds.

Group 4 (Control B): Crystal-Essence Composite, Confi-Quick Dentin Bonding Agent
Using a disposable brush, Confi-Quick, a 37% phosphoric acid gel, was applied to the enamel and dentin of specimens in group 4 for 15 seconds. The etchant was rinsed from the preparation for 15 seconds, and the cavity was dried with oil-free air from a dental syringe for 2 seconds. Care was taken not to dehydrate the tooth surfaces. Confi-Quick dentin adhesive was applied with a disposable brush to thoroughly wet all tooth surfaces and was left undisturbed for 20 seconds. Excessive solvent was removed with a blast of air from a syringe lasting not more than 5 seconds, and the remaining material was cured for 20 seconds.

Immediately, a bulk-filled Crystal-Essence composite restoration was placed over the cured adhesive. The composite was covered with a cellulose strip to counteract the effect of oxygen inhibition and was cured for 40 seconds.

Procedures Common to All Groups
The root apices were sealed with acrylic resin and the teeth coated with two layers of nail varnish, except for the area of the restoration and a 1.00 mm border around the restoration. The specimens were thermocycled for 24 hours (approximately 860 cycles) in water baths held at 5°C and 55°C. The specimens were held for 30 seconds in each bath with a transport time of approximately 20 seconds. The whole apparatus was kept at an ambient temperature of 37° ± 2°C within a "fume-cupboard" for the duration of the thermocycling.

After thermocycling, the samples were immersed in a 0.5% basic fuchsin dye buffered at pH 7 and kept in an incubator at 37°C for 24 hours; subsequently, they were rinsed for 15 minutes in distilled water. The roots of the teeth were cut from the crown, and a section was made through the center of the restorations at right angles to the mesiodistal plane using a slow-speed diamond saw (Accutom, Copenhagen, Denmark). This created two surfaces along which dye penetration could be measured. The extent of microleakage (dye penetration of basic fuchsin) was evaluated for each section under ×40 magnification

TABLE 2. MICROLEAKAGE SCORES.

Composite	Use of Insert	Gingival Score 0	1	2	3	4	Median Score	Occlusal Score 0	1	2	3	4	Median Score
Tetric	No	3	6	1	0	0	1.0	6	3	1	0	0	0.0
	Yes	3	4	3	0	0	1.0	7	2	1	0	0	0.0
Crystal-Essence	No	3	3	4	0	0	1.0	3	4	3	0	0	1.0
	Yes	8	2	0	0	0	0.0	8	2	0	0	0	0.0

Scores: 0 = no dye penetration; 1 = penetration up to 0.5 mm; 2 = penetration up to 1.0 mm; 3 = penetration up to 1.5 mm; 4 = penetration up to the pulpal wall.

using a light microscope. For statistical analysis, each specimen was given the highest score obtained from the two examined surfaces.

The following criteria were used to score the extent of leakage around each specimen:

- Score 0: no dye penetration
- Score 1: penetration up to 0.5 mm
- Score 2: penetration up to 1.0 mm
- Score 3: penetration up to 1.5 mm
- Score 4: penetration up to the pulpal wall

The Kruskal-Wallis test (nonparametric analysis of variance) and Dunn's multiple comparisons test were used to detect differences in microleakage between groups at a probability level of $p < .05$.

RESULTS

Microleakage scores at the gingival and occlusal margins are presented in Table 2. The results of statistical analyses are given in Tables 3 and 4. Preparations restored with an insert and luted with Crystal-Essence showed a significant reduction in marginal microleakage at both occlusal ($p = .0345$) and gingival margins ($p = .0285$) compared with those bulk filled with Crystal-Essence alone. There was a significant difference in only gingival marginal microleakage between restorations restored with an insert and Tetric and an insert and Crystal-Essence ($p = .0345$).

TABLE 3. COMPARISONS OF MICROLEAKAGE AROUND GLASS-CERAMIC INSERTS LUTED WITH DIFFERENT COMPOSITES AND CONTROLS.*

Conditions Compared	Difference in Microleakage (p Value) Occlusal Margins	Gingival Margins
T vs T + I	.7563 (NS)	.6187 (NS)
CE vs CE + I	.0345	.0285
T + I vs CE + I	.6660 (NS)	.0345
T vs CE	.1938 (NS)	.4452 (NS)

CE = Crystal-Essence; I = Glass-ceramic insert; NS = not significant; T = Tetric.
*Using Kruskal-Wallis test (nonparametric analysis of variance) and Dunn's multiple comparisons test; statistical significance is defined as $p < .05$.

DISCUSSION

Contrary to the manufacturer's recommendation, inserts luted with the high-viscous composite, Tetric, showed significantly greater microleakage than inserts luted with Crystal-Essence, a flowable composite, although this occurred only at the gingival margins. The use of different bonding systems may have contributed to this difference more than the composite type or the use of the ceramic insert.

However, the influence of the dental substructure on microleakage cannot be overlooked. In the present study, there was always more microleakage at the gingival margins than at the enamel margins, and this may be explained by microanatomic changes in the orientation and organization of the enamel rods in this area, which do not favor adhesion.[27]

In the present study, inserts were placed in preparations cut without the use of matching burs. Sufficient

TABLE 4. COMPARISONS OF MICROLEAKAGE AT OCCLUSAL AND GINGIVAL MARGINS.*

Conditions Compared	Difference in Microleakage (p Value)
T (occlusal) vs T (gingival)	.3185 (NS)
CE (occlusal) vs CE (gingival)	.8186 (NS)
T + I (occlusal) vs T + I (gingival)	.1159 (NS)
CE + I (occlusal) vs CE + I (gingival)	.9658 (NS)

CE = Crystal-Essence; I = Glass-ceramic insert; NS = not significant; T = Tetric.
*Using Kruskal-Wallis test (nonparametric analysis of variance) and Dunn's multiple comparisons test; statistical significance is defined as $p < .05$.

resin volume may not have been displaced, which would have allowed a reduction in polymerization contraction and stress-related microleakage when Tetric was used. Further studies are required to compare the effect of using matching burs versus non-matching burs to ascertain whether the more accurate matching of the insert and preparation and the concomitant minimization of the luting composite further reduce microleakage. At present, the literature review shows there are no available data that indicate the volume of resin that must be displaced to produce a significant reduction in polymerization shrinkage and stress-related microleakage.

Furthermore, it is difficult to explain the observed results in terms of the linear coefficient of thermal expansion of the three materials. The integration of ceramic inserts into composites reduces the overall coefficient of thermal expansion, which has been shown to reduce contraction and expansion under thermomechanical stress.[13] Teeth and composites are natural insulators and do not register temperature changes quickly during temperature cycling. The coefficient of thermal expansion of dentin is about 8, and that of enamel is about 11. According to the manufacturers, the glass inserts have a coefficient of thermal expansion of about 4. Tetric has a coefficient of thermal expansion of 28, and Crystal-Essence has one of about 38. Although the inclusion of an insert may reduce the overall coefficient of thermal expansion of the system, theoretically, inferior thermal expansion properties would result from the use of the flowable composite compared with a hybrid material according to the above figures.

Two previous studies using virtually the same experimental protocol reported on microleakage around Class V cavities bulk filled or filled with a ceramic insert and composite. Cavities were prepared with a butt margin in the first study, and no detected difference in microleakage between bulk-filled and insert-filled restorations was reported.[21] In the second study, cavities were prepared with a bevel, and the insert-filled restorations showed significantly less leakage than did the bulk-filled cavities.[20] The authors suggested that this was due to the cavity margin design.

There is conflicting evidence regarding the effect of beveled margins on microleakage. Earlier studies tend to support the use of a bevel, but more recent studies using improved bonding agents tend to indicate that there is little difference in dye penetration when small Class V cavities are prepared with or without a bevel.[28]

The cavity design used in this study followed ISO guidelines.[26] These guidelines acknowledge that several types of cavity are of interest when studying leakage and recommend the use of a standard cavity 3 mm in diameter and with a depth of at least 1 mm into dentin in the midpart of the surface of a tooth. Because inserts are normally used clinically in preparations totally in enamel, this type of cavity was chosen in preference to the type recommended by the American Dental Association,[29] which primarily involves the root surface so that no more than 50% of the margin of the restoration involving enamel and more than 75% of the surface area is in contact with dentin in the preparation.

From the protocol used in the present study, it is difficult to explain why there was significantly less microleakage, both occlusally and gingivally, around cavities when an insert was luted with Crystal-Essence compared with cavities bulk filled with Crystal-Essence alone, and no significant difference in microleakage when an insert was used with Tetric compared with cavities bulk filled with Tetric alone. One possible explanation is that the flowable composite has a higher polymerization shrinkage than does the more viscous composite, and, thus, the placement of an insert has more effect.

Essentially, adhesive dentistry can be expressed as a simple relationship between bonds and stresses.[5] Theoretically, the low shrinkage of hybrid materials should reduce interfacial stresses, whereas the higher shrinkage of flowable materials has a potential for higher interfacial stresses. However, the lower rigidity of a flowable, low-viscosity composite may act as a thin, stress-relieving layer and help establish and maintain a bond,[30] whereas the stiffer hybrid may not possess the same stress-relieving properties.

In the present study, the dentin bonding agents used were those recommended by the manufacturers of the composites. Although this introduces a variable into the experimental protocol, this procedure complies with recommended standard practices in which manufacturers' systems are compared.[29] The results could be dependent on the difference between the dentin bonding agents, Confi-Quick being a one-bottle, acetone-based, filler-free material and Excite being a one-bottle, ethanol-based material incorporating extremely fine filler particles. Fillers are added to dentin bonding agents to increase layer thickness. They also alter modulus kinetics, although there is little known about the effect of filler loading on the rigidity of adhesives, which in turn may affect their ability to act as elastic buffers.[31]

It is implicit in other studies that the "wet-bonding technique," as used in the present study, is mandatory for acetone-based materials and leads to optimized diffusivity and hybridization,[32] and the manufacturer of Excite states that the filler particles do not reduce the diffusivity of the material. However, a recent study showed that the use of Excite produced a thin, hybrid layer and a demineralized zone that was not fully infiltrated with resin monomer.[33]

Interestingly, it has been reported that microleakages around Class II cavities, restored with either ceramic inserts or bulk-filled composite, were not found to be significantly different, and the main factors influencing the outcome were considered to be the choice of bonding agent and/or the pretreatment procedures.[23]

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are discussed in this article.

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