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Gingival Microleakage of Class II Resin Composite Restorations with Fiber Inserts

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Clinical Relevance

Fiber inserts incorporated at the gingival floor of Class II composite restorations resulted in a significant reduction of microleakage scores as compared to restorations made without inserts. This may lead to a reduced incidence of recurrent caries.

SUMMARY

Purpose: This investigation evaluated the effect of glass and polyethylene fiber inserts on the microleakage of Class II composite restorations with gingival margins on root surfaces. Methods: Fifty-four intact molars were sterilized with Gamma irradiation and mounted in acrylic bases. Class II slot cavities were made on both proximal sides of each tooth (3 mm wide, 1.5 mm deep) with the gingival margin on the root surface. The teeth were divided into nine groups, according to the technique of restoration and type of bonding agent. Filtek P-60 (3M/ESPE) was used to restore all cavities. Two types of fiber inserts were used: glass fiber (Ever Stick, StickTech) and polyethylene (Ribbond-THM), with three bonding agents being employed: Scotch Bond Multipurpose (3M/ESPE), Clearfil SE Bond (Kuraray) and Xeno IV (Dentsply). In the experimental groups, 3 mm long fiber inserts were inserted into restorations at the gingival seat. The control groups had no fiber inserts. The restorations were made incrementally and cured with LED light (UltraLume5, Ultradent). The restored teeth were stored in water for two weeks, then thermocycled for 3,000 cycles (5°C and 55°C). The tooth surfaces were sealed with nail polish, except at the restoration margins. The teeth were immersed in 2% procion red dye solution, sectioned and dye penetration was assessed to determine the extent of microleakage

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according to a six-point scale. Results: The fiber groups generally showed reduced microleakage scores compared to the control groups. The Clearfil SE Bond (Kuraray)/Filtek P-60 (3M/ESPE) combination produced the lowest degree of microleakage, irrespective of fiber type. However, the glass fiber groups were more consistent in reducing microleakage than the polyethylene groups. Conclusions: The use of fiber inserts significantly reduced gingival microleakage in Class II composite restorations with gingival margins in dentin, irrespective of the adhesive used. Clearfil SE Bond (Kuraray)/Filtek P60 (3M/ESPE) produced the lowest microleakage scores.

INTRODUCTION

Tooth-colored posterior restorations, in particular, direct resin composites, are now the treatment of choice for most patients. However, resin composite materials undergo a volumetric polymerization contraction of at least 2.0%,[1] which may result in gap formation as the composite pulls away from cavity margins during polymerization.[2] Such gaps can result in the passage of salivary fluid along the tooth restoration interface, resulting in microleakage.[3]

Microleakage is one of the most frequently encountered problems with posterior composite restorations, especially at gingival margins placed apical to the cemento-enamel junction (CEJ), as in deep Class II cavities.[4-7] Recurrent caries at the gingival margin of Class II restorations with subsequent failure of the restoration has been attributed to such microleakage.[8] Efforts have been made to develop methods to decrease this problem with Class II composite restorations. This includes techniques for light polymerization aimed at reducing the amount of composite volumetric shrinkage, reducing the ratio of bonded to unbonded restoration surfaces (C factor) and following strategic incremental placement techniques to reduce residual stresses at the tooth/restoration interface.[2,9] The directed polymerization shrinkage technique was developed to help direct polymerization shrinkage towards the tooth, rather than towards the center of the composite mass.[10] Resin-modified glass ionomer cements were placed in the gingival portion of Class II composite restorations in an attempt to reduce microleakage.[11-12] A transparent, cone-shaped light-tip was developed for use with the light guide to reduce cervical contraction and gap formation in Class II composite restorations by transmitting the curing light through the first composite increment in the proximal box, while simultaneously maintaining pressure.[13]

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 reduced.[14] Glass-ceramic inserts that are directly placed in resin composite restorations to improve restoration adaptation through limiting the total amount of volumetric polymerization shrinkage have been developed.[15-22] However, their usefulness in this respect has been controversial, with some studies showing that inserts improve the performance of posterior composite restorations,[18-19,21] while other studies reported little or no significant improvement.[20,22]

Over the last few years, new dental products containing glass, polyethylene, quartz, carbon or other fibers have been made available. These products are meant to improve the mechanical properties of materials and provide extended applications for resin composites.[23-30] They have a wide range of applications, including orthodontic treatment,[31] such as splints for periodontally-involved teeth,[32-33] reinforcement for resin composites,[34] the fabrication of non-metallic endodontic posts,[35-39] reinforcement of denture bases[40-44] and reinforcement for non-metallic crowns and fixed partial dentures.[25-26,45-51] It has been reported that the embedding of fiber inserts into composites results in strengthening the restoration, particularly large ones, with improved fracture resistance.[30]

This study determined the effect of glass and polyethylene fiber inserts on reducing the gingival marginal gap in Class II resin composite restorations with gingival margins on the root surface. This was achieved through determining microleakage scores along the tooth/restoration interface when three different types of bonding agents were used.

METHODS AND MATERIALS

Fifty-four intact molars were selected from a pool of extracted teeth. First, they were sterilized with Gamma irradiation, then they were cleaned with periodontal scalers and rotary brushes. Next, the molars were mounted in acrylic bases up to 2 mm apical to the CEJ and stored in distilled water in a refrigerator until restoration.

Class II slot cavities were made on both proximal sides of each molar using a #245 tungsten carbide bur (SS White, Great White Series, Lakewood, NJ, USA) in a water-cooled high-speed air turbine handpiece. All line angles were rounded. The gingival floor of the slot cavities was located at least 1.0 mm below the CEJ on the root surface. Each slot cavity measured 3.0 mm wide buccolingually and 1.5 mm in axial depth. A new bur was used for every four cavity preparations. The dimensions of the cavities were verified with a periodontal probe. One operator performed all cavity preparations, while another investigator checked the cavities before restoration, to ensure that they conform to the dimensions. Those teeth with prepared cavities were randomly divided into nine groups.

A universal metal matrix band/retainer (Tofflemire) was placed around each prepared tooth and was supported externally by applying low-fusing compound to maintain adaptation of the band to the cavity margins. Each cavity was cleaned with water spray and was air-dried for five seconds. The predetermined bonding agents assigned to each group were applied according to manufacturers instructions (Table 1). A new Ultralume 5 (Ultradent, South Jordan, UT, USA) light polymerization unit was used. A posterior resin composite (Filtek P60, shade B2, 3M/ESPE) was used to restore all cavities. The restorations were divided into nine groups according to the assigned type of bonding agent and fiber insert (Table 2). Cavities without fiber inserts were used as controls. An approximate 2 mm layer of P-60 was carefully adapted onto the gingival floor and light-polymerized for 40 seconds. A second increment was added diagonally on one side and light polymerized for 40 seconds. Third and fourth increments, filling up the remainder of the box, were placed and similarly light polymerized.

Table 1: *Materials Used in the Study with Their Manufacturers Information and Lot Numbers*

Material	Brand Name	Manufacturer	Lot #
Bonding agents	Scotch Bond Multi Purpose	3M ESPE, St Paul, MN, USA	4AN
	Clearfil SE Bond	Kuraray Medical Inc, Sakazu, Kurashiki, Okayama, Japan	61617
	Xeno IV	Dentsply Caulk, Dentsply-International Inc, Milford, DE, USA	050119
Resin composite	Filtek P-60	3M ESPE, St Paul, MN, USA	4PG
Fiber inserts	everStick POST 0.9 (glass fiber)	Ever Stick, StickTech, Turku, Finland	2040419-P1-007
	Ribbond-THM (polyethylene fiber)	Ribbond-THM, Seattle, WA, USA	9538

Table 2: *Distribution of the Experimental Groups Among the Three Bonding Agents and the Two Types of Inserts*

Group	Bonding Agent	Fiber Insert
G 1 (control)	Scotch Bond Multipurpose	-
G 2		Glass Fiber
G 3		Polyethylene Fiber
G 4 (control)	Clearfil SE Bond	-
G 5		Glass Fiber
G 6		Polyethylene Fiber
G 7 (control)	Xeno IV	-
G 8		Glass Fiber
G 9		Polyethylene Fiber

Cavities with fiber inserts were used for restorations. A less than 1 mm thick amount of resin composite was first placed on the gingival floor. Then, a 3 mm piece of fiber insert was placed onto the composite increment and condensed through it to adapt it against the gingival floor, displacing the composite to fill into the corners of the box (Figure 1). Light-polymerization followed for 40 seconds from the occlusal cavity. Three other diagonal layers of resin composite were placed and polymerized, as with the mesial cavity. Great care was taken during insertion of the final resin composite increment in order to keep finishing to a minimum. Only the occlusal surfaces were then finished with 30-bladed tungsten carbide burs (H 135 UF, H 379 UF, H 246 LUF, Brasseler USA, Savannah, GA, USA) in a high-speed handpiece with water-cooling. Polishing followed with aluminum oxide points (Jiffy Points, Ultradent). One operator performed all restorations, while another investigator checked the restorations to ensure that they were free of defects (Figure 2). The specimens were then stored in distilled water at 37°C for two weeks.

All specimens were then subjected to 3,000 thermocycles between 5°C and 55°C in water baths with a 30-second dwell time. Apical foramina of the teeth were then sealed with glass ionomer cement. Two layers of nail varnish were applied on the tooth surfaces, except for 1 mm short of the tooth-restoration margins. The teeth were then immersed in a 2% procion red solution for 24 hours at 37°C, after which the teeth were removed from the dye solution and rinsed with tap water for five minutes. Each tooth was then sectioned mesiodistally with a microslicing machine (Isomet, Buehler, Lake Buff, IL, USA) into three sections. The section with the deepest dye penetration was selected to represent the tooth. The extent of dye penetration was determined by examination with a light microscope according to a six-point scale: 0 = no leakage, 1 = leakage extending to the outer half of the gingival floor, 2 = leakage extending to the inner half of the gingival floor, 3 = leakage extending through the gingival floor up to 1/3 of the axial wall, 4 = leakage extending through the gingival wall up to 2/3 of the axial wall, 5 = leakage extending through the gingival wall up to the DEJ level. Two examiners evaluated the extent of dye penetration for each selected tooth section. In case of disagreement, a third examiner evaluated and resolved the dispute. Data were statistically analyzed with non-parametric Kruskal-Wallis test and Mann-Whitney U test.

Table 3: *Microleakage Scores Distribution Among the Test Groups with Means and Standard Deviations*

Groups		**Microleakage Scale**						**Mean**	**SD**
		0	1	2	3	4	5		
Scotch Bond Multipurpose	G1	4	3	3	1	1	1	1.62	1.61
	G2	6	3	3	-	-	-	0.75	0.87
	G3	5	3	1	1	1	1	1.42	1.73
Clearfil SE Bond	G4	5	6	1	-	-	-	0.67	0.65
	G5	9	4	-	-	-	-	0.31	0.48
	G6	11	2	-	-	-	-	0.15	0.38
Xeno IV	G7	4	8	1	-	-	-	0.77	0.60
	G8	8	1	3	-	-	-	0.58	0.90
	G9	6	3	1	1	-	-	0.73	1.01

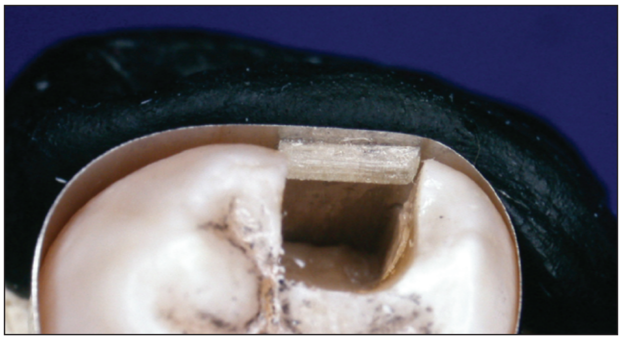

Figure 1. *Glass fiber insert cut to fit the width of the slot cavity, 3 mm, and will be inserted into the depth of the box. A small increment of composite was already placed in the depth of the box.*

Figure 2. *Molar with completed slot restoration. Note the location of the gingival margin on the root surface.*

Figure 3. *Representative specimen from group 1 (left), showing slot cavity restored without insert, and from group 2 (right), showing a slot cavity restored with insert. Scotchbond Multi-Purpose was used as the bonding agent. Red indicates dye leakage along the interface.*

RESULTS

The means and standard deviations of microleakage scores for all groups are presented in Table 3. Generally, specimens from groups with inserts had lower scores than the control groups (without inserts). In particular, Clearfil SE Bond produced the lowest degree of microleakage among the three adhesives, and, among all groups, those with glass fiber inserts had the most consistent results.

The Kruskal-Wallis test revealed significant differences in mean microleakage scores among the groups ($p<0.05$). Further analysis with the Mann-Whitney U test showed significant differences in mean microleakage scores between the control groups and the groups with fiber inserts ($p<0.05$). However, for all group sets, no significant differences were detected between the mean microleakage scores of the glass fiber and polyethylene fiber groups ($p>0.05$).

Figures 3 through 6 show representative tooth sections belonging to groups with three adhesives. The restorations without inserts had microleakage along the gingival floor/restoration interface, with some dye penetration through the dentinal tubules towards the pulp. Figure 7 shows a bar chart of the mean microleakage scores for all groups.

DISCUSSION

Gamma irradiation was used to sterilize the teeth, as it is both effective and has no adverse effects on the structure of dentin and its permeability.[61-62] It is also reported that gamma irradiation neither affects the shear bond strength to dentin nor alters the dentin surface morphology.[61-62]

Microleakage of composite restorations occurs due to stresses placed along the tooth/restoration interface from polymerization shrinkage, temperature fluctuations in the oral environment and mechanical fatigue-cycling through repetitive masticatory loading.[1,52] Contaminants infiltrate through the formed gap, with subsequent sequela, such as post-operative hypersensitivity and recurrent caries, which may warrant restoration replacement.[53-54] Previous studies reported that composite restorations showed relatively greater

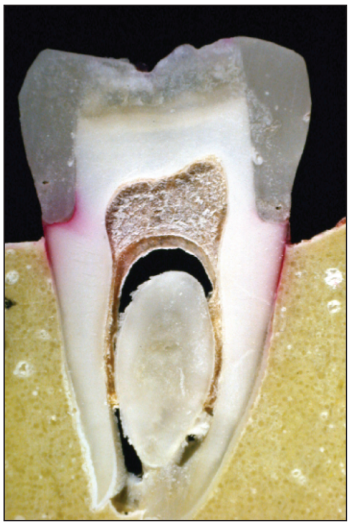

Figure 4. *Representative specimen from group 4 (left), showing slot cavity restored without insert, and from group 5 (right), showing a slot cavity restored with glass fiber insert. Clearfil SE Bond was used as the bonding agent. Red indicates dye leakage along the interface.*

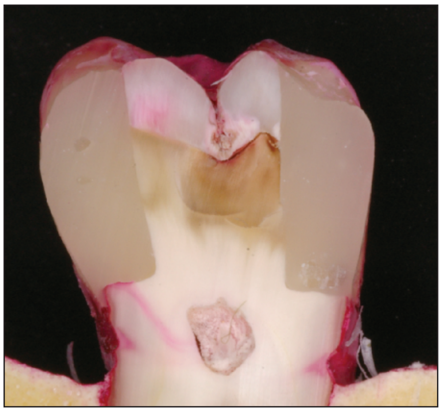

Figure 5. *Representative specimen from group 7 (left), showing a slot cavity restored without insert, and from group 8 (right), showing a slot cavity restored with a glass fiber insert. Xeno IV was used as the bonding agent. Red indicates dye leakage along the interface. Leakage along the gingival interface extended through the dentinal tubules towards the pulp (left).*

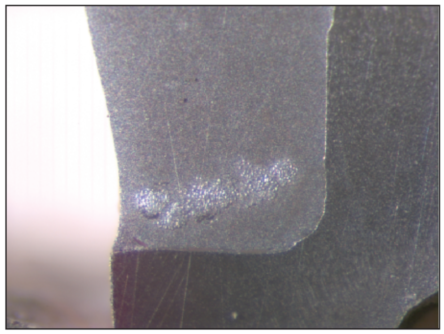

Figure 6. *SEM image showing the gingival aspect of a composite slot restoration with glass fiber inserts.*

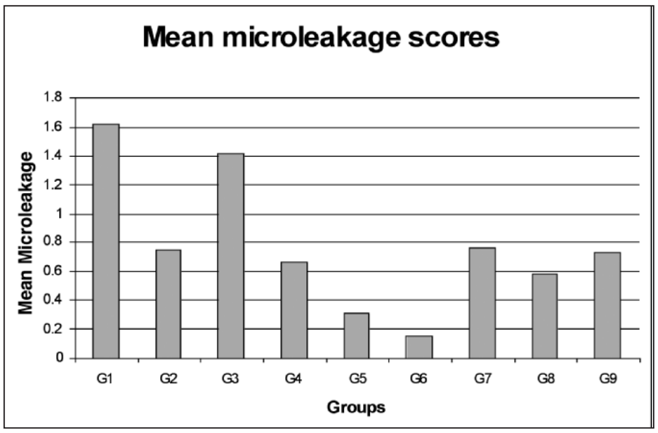

Figure 7. *Mean microleakage scores for the nine experimental groups.*

microleakage at the gingival rather than the occlusal margins.[4-7] The most likely cause for this phenomenon is polymerization contraction characteristics, including shrinkage towards the center of the restoration, towards the "stronger" enamel-composite joint and towards the light source.[55] The magnitude of contraction may be so great that water sorption and stress relaxation cannot compensate for it.[56]

When glass inserts are placed at the gingival margins of Class II composite restorations, they enhance the quality of the marginal area in two ways. First, the fibers replace part of the composite increment at this location, resulting in a decrease in the overall volumetric polymerization contraction of the composite. Second, the fibers assist the initial increment of composite in resisting pull-away from the margins toward the curing light. The fibers also may have a strengthening effect of the composite margin, which may increase resistance to dimensional change or deformation, which occurs during thermal and mechanical loading, and, hence, improve marginal adaptation.[60]

For light-polymerization of the first increment placed in the depth of the cavity, the deep slot cavity preparation configuration used in this study is challenging. The light must travel approximately 4 mm before it reaches the surface of the first composite increment. This may affect the degree of monomer conversion of this increment, as the light will be less effective compared to subsequently placed increments at levels closer to the occlusal surface. However, the light unit used in this study produced light with high power density and, as a result, would be expected to sufficiently polymerize the first increment in the depth of the cavity.

Thermocycling is widely used in dental research, particularly when testing the performance of adhesive materials. It aims to thermally stress the adhesive joint at the tooth/restoration interface. This process may highlight a mismatch in the thermal coefficient of expansion between the restoration and tooth structure (dentin), which results in different volumetric changes during temperature fluctuations, causing fatigue of the adhesive joint with subsequent microleakage.[64] The effect of thermocycling on resin composite restorations is controversial; some authors reported that it has a significant effect on microleakage, especially when the gingival margins of the preparation are located in dentin,[65] while others believe that thermocycling has an effect on microleakage only if the restorative material has a higher coefficient of thermal expansion (metallic restorations).[66] In the current study, all specimens were subjected to 3,000 cycles, which equates to a number of years of intraoral thermocycling.

The three adhesives used in this study represent three current systems. ScotchBond Multipurpose, a three-step conventional adhesive, was used as a control. Clearfil SE Bond, a two-step self-etching adhesive, was reported to have superior bonding to dentin.[67-68] Xeno IV, is a new one-step self-etching adhesive used for comparison purposes. Two types of fibers were used as inserts: EverStick Post 0.9 mm (glass fiber) and Ribbond-THM (polyethylene fiber). EverStick glass fiber is translucent, silanized and bonds well to resin composite. It is formed of a large number of unidirectional glass fibers embedded in a resin matrix, while Ribbond THM is made from a high concentration of thin (small diameter) braided fibers.

Results of the current study showed that fiber inserts significantly reduced the microleakage of resin composite at the gingival margin. Kolbeck and others[69] stated that the reinforcing effect of glass fibers was more effective than that of polyethylene fibers, and this was attributed to the difficulty in obtaining good adhesion between the polyethylene fibers and the resin matrix. However, Hamza and others[70] found no significant difference between the reinforcing effects of glass and polyethylene fibers, which may be due to the use of silane coupling agent and plasma treatment to increase the degree of adhesion of the polyethylene fibers to the resin. This may explain the similarity in mean microleakage scores between groups restored with the two types of fiber inserts in this study, as the polyethylene fibers were plasma-treated by the manufacturer.

CONCLUSIONS

1. The use of fiber inserts significantly reduced microleakage in Class II resin composite restorations with gingival margins on the root surface, irrespective of the adhesive used.
2. A two-step self-etch adhesive produced the lowest microleakage scores when used with Filtek P-60 posterior composite.

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