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Leakage Pathway of Class V Cavities Restored With Different Flowable Resin Composite Restorations

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Clinical Relevance

The flowable resins evaluated in this study showed leakage patterns (micro and nano), indicating that the bonding system used did not achieve perfect sealing at the restor- tion/dentin interface.

SUMMARY

This study investigated the leakage pathway of facial and lingual Class V cavities restored with different flowable resin composites bonded with one bonding agent by examining the resin/dentin interface. Forty Class V cavities were etched with 37% phosphoric acid gel; Single Bond dental adhesive was applied, then the cavities were randomly divided into four groups (n=10). Three groups were restored with one of three flowable resin composites (Grandio Flow, Filtek Flow and Admira Flow). The fourth group was restored with Z250 (hybrid resin composite) to serve as a control. The specimens were then placed in 50% w/v silver nitrate solution for 24 hours and immersed in a photodeveloping solution for eight hours. Thereafter, the specimens were sectioned bucco-lingually, polished, mounted on stubs, gold sputter coated and examined by scanning electron microscope.

Silver particle penetration length with and without gap formation was measured directly on the scanning electron microscope monitor and calculated as a percentage of the total length of the cut dentin surface that was penetrated by silver nitrate. The data were analyzed with one-way ANOVA and Tukey HSD test. The groups restored with Filtek Flow and Admira Flow showed a microleakage pattern where silver nitrate penetration was observed with gap formation at the tooth/restoration interface and Filtek Flow recorded significantly higher leakage than Admira Flow. Grandio Flow showed similar marginal adaptation to Z250 resin composite with no gap formation at the interface. However, silver ions had penetrated beneath the resin-impregnated layer in cavities restored with Grandio Flow and Z250, indicating nanoleakage occurred. This study suggests that volumetric shrinkage in resin composites remains a problem. Although some new technologies are trying to solve the

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problem of composite shrinkage, the bonding system used in this study did not achieve perfect sealing at the restoration/dentin interface. This might affect durability of the bond to dentin.

INTRODUCTION

Despite improvements in the current formulations of resin composite, polymerization shrinkage remains a problem.[1] The polymerization shrinkage of resin composite may induce mechanical stresses on tooth structure through the bond to enamel and dentin.[2] These stresses can contribute to failure of the weakest portions of a composite-dentin interface.[2-3] This process can cause micrometer-wide marginal gaps, thus opening a path for the migration of microorganisms and potentially inducing secondary caries.[4] Several materials and methods have become advocated to minimize development of this gap. Current dentin adhesive systems that created a hybrid layer between resin and dentin have shown improved marginal seal due to the use of acidic molecules and improved bonding technology.[5] Another approach to creating a gap-free bond is the use of an elastic intermediate layer of resin between the composite and adhesive resin, which may absorb contraction stress of the composite during polymerization.[6-7] However, in 1995, Sano and others[8] described a leakage pathway through the porous zone at the hybrid layer-adhesive interface without gap formation. This leakage is not the classical microleakage that can be seen by conventional 10-30x microscopic magnification. Rather, it represents a leakage that occurs within nanometer-sized spaces in the base of the hybrid layer that have not been filled with adhesive resin or which were left when poorly polymerized resin was extracted by dentinal fluid. To distinguish this leakage from the typical microleakage, it was called nanoleakage. In order to quantify the degree of nanoleakage, silver nitrate penetration has been used for scanning electron microscopy (SEM) investigation.[9-10] The amount of silver penetration depends on the type of bonding agent and the different parameters of the application technique, such as etching time and dentin moisture.[11]

Flowable composites were introduced in late 1996.[12] They have a filler size similar to hybrid composites but lower filler content (60%-70% by weight and 60%-75% by volume).[13] The reduced filler loading of flowable composites compared with their hybrid analogs leads to enhanced flow and reduced elastic modulus.[13] The lower elastic modulus indicates that flowable composites have a greater ability to flex with the tooth than stiffer restorative materials.[14] Also, this material may act as a stress-breaker and seems to wet the cavity more completely than conventional sticky resin-based restorative materials.[14-15] However, Braga and others[16] showed that flowable composites produced polymerization contraction stress similar to hybrid composite. Also, Chimello and others[17] and Estafan and others[18] found no difference in the occlusal or cervical microleakage of cavities restored with flowable or hybrid resin composites.

In addition to hybrid flowable resin composite, many relatively recent classes of flowable composites have been introduced. From these classes come Ormocers (organic modified ceramic) and nanotechnology flowable composites.[19-20] Flowable composites have been advocated as a lining in Class I and II hybrid resin composite restorations and as a restorative material in small Class V cavities.[19]

Using one bonding agent, this study investigated the leakage pathway of Class V cavities restored with different flowable composites under SEM evaluation.

METHODS AND MATERIALS

Twenty freshly extracted caries-free human third molars were cleaned and examined with a stereomicroscope to exclude any cracked teeth. Saucer-shaped cervical cavities, approximately 2.5 mm in diameter and 1.5 mm deep, were prepared on both the buccal and lingual surfaces of each tooth using round carbide burs (Midwest Dental Products Corp, Des Plaines, IL, USA) in a high-speed handpiece under water spray. Butt-joint occlusal and gingival margins were located 1.5 mm above the cemento-enamel junction and 1 mm below the cemento-enamel junction, respectively.

The teeth were randomly divided into four groups, with each group containing 10 cavities. One bonding agent, Single Bond (3M Dental Products, St Paul, MN, USA), three flowable composites: Grandio Flow (Voco GMBH, Cuxhaven, Germany), Admira Flow (Voco GMBH) and Filtek Flow (3M Dental Products) and one microhybrid resin composite Z250 (3M Dental Products) were used to restore the prepared cavities following the manufacturer's recommendations. Before restoration, all cavities were etched with 37% phosphoric acid gel (Kuraray Co, Ltd, Osaka, Japan) for 15 seconds, rinsed with water for 20 seconds and blotted dry, leaving the dentinal surfaces slightly moist. Two consecutive coats of the adhesive were then applied to the cavity walls; they were then lightly air dried and light cured for 10 seconds with a Heliolux light-curing unit (Vivadent USA, Amherst, NY, USA). The first three groups were restored with one of the tested flowable composites. The fourth group was restored with Filtek Z250 to serve as a control. The flowable restorative materials were injected as one increment into the cavity, while Z250 was placed with a bulk placement technique. After light curing for 40 seconds, all the restorations were finished and polished with Sof-Lex disks (3M Dental Products). During polishing, all the specimens were checked with a light microscope (Wild Photomakroskop M400, Heerbrugg,

Table 1: *Mean Percentage and Standard Deviations (SD) of Silver Nitrate Penetration With and Without Gap Formation*

Material	N	Mean (SD) Percentage of Silver Nitrate Penetration with Gap Formation Microleakage	N	Mean (SD) Percentage of Silver Nitrate Penetration Without Gap Formation Nanoleakage
Z250	1	2.10 (7.2)a	19	24.4 (5.7)a
Grandio Flow	0	0	20	13.1 (5.1)b
Admira Flow	20	19.5 (5.1)b	0	0
Filtek Flow	19	25.8 (7.5)c	0	0

Means with the same letters are not significantly different at $p<0.05$ *for each column.*

Switzerland) at 20x magnification to ensure no flash remained along the margins of the restorations. If flash still remained, the specimen was re-polished until no flash was visible under the microscope. All the experimental teeth were then thermocycled for 1500 cycles in a thermocycling apparatus (MCT2, AMM 2 instrument, Sao Paulo, SP, Brazil) between water baths of 5°C ± 2°C and 55°C ± 2°C, with a dwell time of 60 seconds and a transfer time of 30 seconds between each bath. After thermocycling, the root apices and the occlusal portions of each tooth were sealed with a Silux Plus resin composite material (3M Dental Products). The entire surface of each tooth was coated with a clear non-fluorescent nail polish to ensure a perfect seal, except for 1 mm, around the circumference of the restoration margins. The teeth were then placed in 50% (w/v) silver nitrate solution for 24 hours in total darkness. The teeth were then were rinsed under running water for five minutes, immersed in photodeveloping solution and exposed to fluorescent light for eight hours so that silver ion reduction to metallic silver would be completed.[9-10] The teeth were removed from the developing solution, rinsed thoroughly and sectioned bucco-lingually with a low-speed, water-cooled diamond saw (Model 650, South Bay Technology Inc, San Clement, CA, USA). A total of 20 specimens were obtained for each group. All of the cut surfaces were ultrasonically cleaned, air dried, mounted on stubs, left to rest for 24 hours in a tight container, gold sputter coated (Polaron E-5200 Energy Beam Sciences, Agawan, MA, USA) and examined by SEM (JSM, 6360LV, JEOL, Tokyo, Japan).

The marginal micromorphology of each restoration was examined and recorded following the method described by Sano and others.[8] The length of any gap or silver penetration along the preparation wall was examined under both low (200x) and high (1000x) magnification, since, in some cases, the loosely distributed silver particles could not be observed under the lower magnification. The length of the gap and the internal cavity walls or the silver penetration along the preparations was quantitatively analyzed directly on the SEM monitor using a multi-point measuring device. The leakage scores were calculated as the percent of the total cut dentin surface that was penetrated by the silver nitrate or P/L x 100, where P= length of the gap or length of silver nitrate penetration along the resin/dentin interface and L= total length of the dentinal cavity wall on the cut surface. The results were statistically analyzed by one-way ANOVA and Tukey HSD tests at a 0.05 significant level.

RESULTS

Table 1 shows the mean percentage and standard deviations of the silver nitrate penetration with and without gap in the experimental groups. All the samples restored with Filtek Flow and Admira Flow demonstrated marginal gap formation at the tooth/restoration interface with silver nitrate penetration, which indicates microleakage. Cavities restored with Filtek Flow showed significantly higher leakage scores compared to those restored with Admira Flow (p=0.024). One sample restored with Filtek Flow was excluded from the study, because of severe deposition of silver nitrate inside the dentinal tubules, making it difficult to quantify the silver nitrate.

On the other hand, silver nitrate penetration without gap formation was observed only in cavities restored with Z250 and Grandio Flow resin composite, which indicates nanoleakage. Grandio Flow showed significantly less nanoleakage scores than Z250 (p=0.001). However, only one cavity restored with Z250 resin composite showed true gap formation.

The leakage pathways and patterns revealed by SEM imaging of representative resin/dentin interfaces are shown in Figures 1-4. No penetration of silver nitrate or gap formation was detected at the enamel margin of the restorations. Thus, only the cementum/dentin margins were photographed by the SEM.

Different nanoleakage patterns were observed in the groups restored with Grandio Flow and Z250 resin composite. The silver nitrate depositions were observed mostly at the base of the hybrid layer (Figure 3) and diffused within the hybrid layer (Figure 4).

DISCUSSION

Silver nitrate was selected in this study, because it has been accepted as a suitable method for measuring both microleakage and nanoleakage.[21] The silver ion is very small (0.059 nm-diameter) when compared to the size of a typical bacterium (0.5-1.0 µm).[22] This small size, and

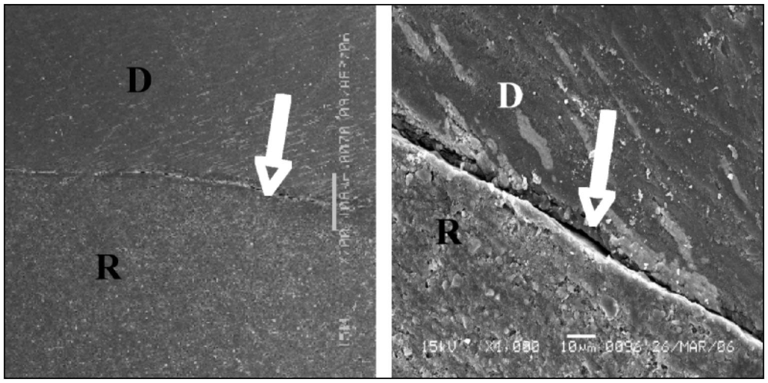

Figure 1. *Low and high magnification SEM image (200x and 1000x) of the interface between Filtek Flow resin composite and dentin with gap formation and silver nitrate deposition at the restoration side. D= Dentin, R= Restoration; arrow indicates gap.*

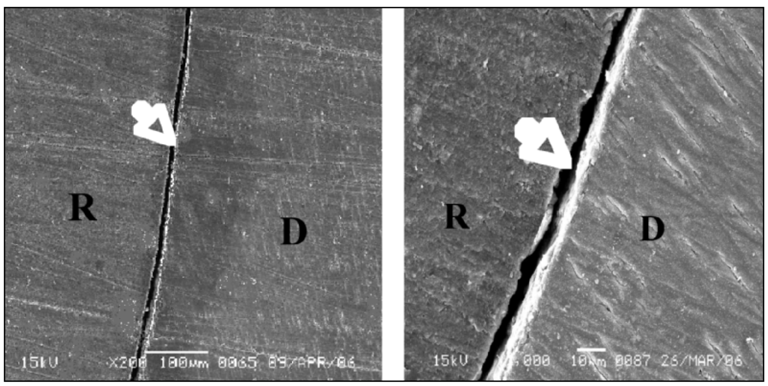

Figure 2. *Low and high magnification SEM image (200x and 1000x) of the microleakage pattern shown at the interface between Admira Flow and dentin. The gap was noticed at the interface with silver nitrate deposition at the dentin side. D= Dentin, R= Restoration; arrow indicates gap.*

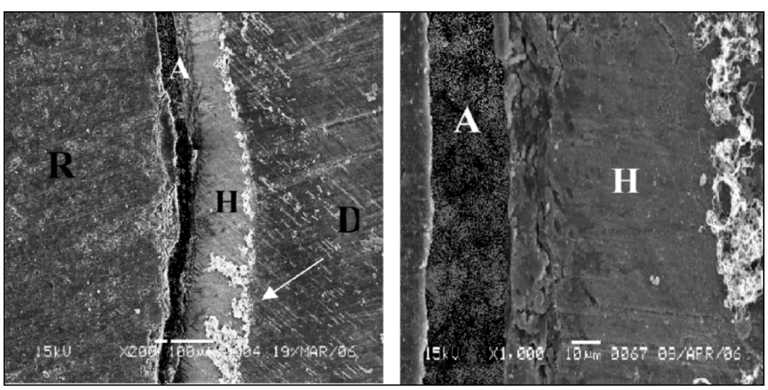

Figure 3. *Low and high magnification (200x and 1000x) SEM image of the interface between Grandio Flow resin composite and dentin. No gap was seen at the interface. However, silver nitrate deposition was noticed at the bottom of the hybrid layer. D= Dentin, R= Restoration, A= Adhesive, H= hybrid layer; arrow indicates silver nitrate.*

a high reactivity to stain after binding tightly to any exposed collagen fibrils that are not enveloped by the adhesive resin, makes sliver nitrate the most appropriate agent to detect nanoporosities within the hybrid layer.[23]

Clinical failure of resin composite restorations due to disruption of the bonded interface between composite and dentin remains a frequent occurrence.[1] Such interfacial defects may develop as a consequence of long-term thermal and mechanical stresses or during the restorative procedure itself, due to stresses generated by composite polymerization shrinkage.[24-25] It has been reported that marginal gaps increase as cavity design changes from a V-shaped to a box-shaped configuration. The term "cavity configuration factor" (C-factor) has been used to describe the difference in cavity design.[26] A high C-factor, which indicates a high number of bonded to unbonded composite surfaces, corresponds to a high stress value.[26] Hence, saucer-shaped, shallow cavities were employed in this study to reduce composite contraction stress.[27] Also, all samples in this study were exposed to the same thermal stress through thermocycling. However, gap formation was observed at the composite/dentin interface mostly in cavities restored with Filtek Flow and Admira Flow. The gaps found in the current study were considered true gaps, because, by using silver nitrate staining, the artifactual gaps created upon high vacuum dehydration during specimen preparation for SEM can easily be differentiated from true gaps by the absence of silver staining along the gap border.[28]

In the current study, one bonding agent was used with the four restorative materials in order to study the leakage pathway of the resin composites and to exclude variation of the different bonding systems to eliminate marginal leakage. Nevertheless, the different materials showed different leakage pathways. Filtek Flow and Admira Flow showed typical microleakage manifested as gap formation at the tooth/restoration interface. This indicates polymerization shrinkage, which results in resin pulling away from dentin, leading to gap formation. On the other hand, Grandio Flow showed similar behavior to the hybrid restorative Z250, where gaps were rarely seen. Instead, the last two materials showed the typical leakage pathway that was described by Sano and others[8] and termed as nanoleakage.

The different behavior of the four materials could be attributed to the differing chemistry of these materials. Volumetric shrinkage experienced by composite is determined by several factors, including its filler volume.[15] Flowable composites present higher volumetric shrinkage than hybrid composites due to their reduced filler content and increased resin matrix.[29] Filtek Flow has 47% filler by volume and Admira flow has 50% filler by vol-

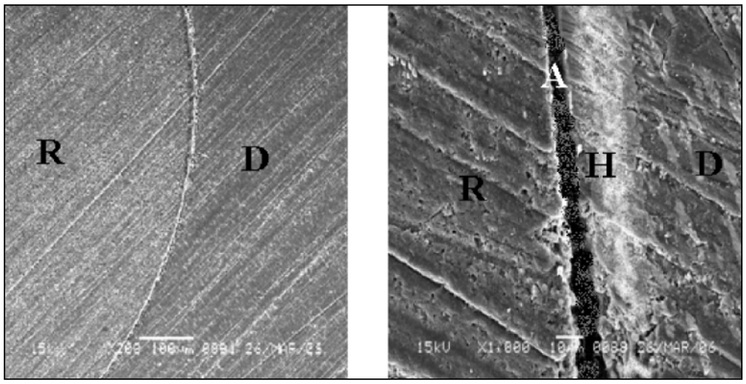

Figure 4. *Low magnification (200x) of SEM image at the interface between Z250 resin composite and dentin. Excellent adaptation of the restoration and no gap can be seen. At higher magnification (1000x), silver nitrate deposition can be seen within the hybrid layer. D= Dentin, R= Restoration, A= Adhesive, H= hybrid layer.*

ume, which might explain the reason for their volumetric shrinkage. On the other hand, Grandio Flow is a nanofilled composite, which has higher filler loading (65.6%) than the hybrid Z250 resin composite (60%). This might explain the low volumetric shrinkage of Grandio Flow and, subsequently, its resistance to gap formation. It was not the intent of this work to measure volumetric shrinkage or contraction stress of flowable composites. However, polymerization shrinkage frequently manifests as resin pulling away from dentin, leading to gap formation.[14]

Although almost no gaps were found in cavities restored with Grandio Flow and Z250 hybrid resin composite, another pathway for leakage was observed. Silver nitrate deposition was noticed within the hybrid layer, which indicates that even if the restorative material resists shrinkage, the adhesive systems are still unable to completely eliminate marginal leakage. The bonding system that was used (Single Bond) is a single-bottle system, where the adhesive and primer are combined in one bottle. It is possible that the lack of a separate primer may reduce the infiltration depth of the adhesive resin in demineralized collagen fibrils, thus reducing the adhesion and sealing capacity.

Post-operative sensitivity and restoration loss have been reported to be the most frequent sequela of gap formation (microleakage) between enamel or dentin and the restorative material. However, nanoleakage within the hybrid layer cannot allow microorganism migration within the tooth structure, because the pore size in partially hybridized dentin is too small.[30] Nevertheless, this kind of leakage may allow for the penetration of bacterial products and oral fluid along the interface, which may result in hydrolytic breakdown of either the adhesive resin or collagen within the hybrid layer. This could compromise the stability of the resin dentin-interface.[31]

CONCLUSIONS

Within the limitations of this study, the following conclusions can be made:

- Filtek Flow and Admira Flow resin composite showed a significant microleakage pattern with gap formation at the restoration/dentin interface.
- Grandio Flow showed a similar leakage pattern to Z250 hybrid resin composite, where no gaps were seen at the restoration/dentin interface. Silver ions penetrated beneath the resin-impregnated layer, which is consistent with nanoleakage.
- The bonding system used in this study did not achieve perfect sealing at the restoration/dentin interface.

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