Comparison of microleakage of different margin types around Class V resin restorations in primary teeth

ABSTRACT

Aim This in vitro study compared the effect of a concave with a straight-bevelled cavity margin on the microleakage of Class V composite resin restorations in primary teeth.

Materials and methods Standardised Class V cavity preparations were made in vitro on the buccal (all margins placed in enamel) and on the lingual (margins placed in enamel and cementum) surfaces of 20 sound primary molars. The teeth were randomly assigned to two groups of 10 each: in Group 1, a concave bevel was made with a high-speed No. 04 tungsten carbide bur and in Group 2, a straight bevel was made with a high-speed No. 556 tungsten carbide bur. The teeth were restored incrementally with Adper™ Single Bond 2 (3M) adhesive and Filtek™ Z 350 (3M) composite resin. All specimens were subsequently thermocycled and immersed in 50% silver nitrate solution. Microleakage of the restorations was then assessed by silver penetration. A grading scale of 0 to 4 was used as the scoring criterion.

Results At the enamel margins no statistically significant differences were observed between the two groups (p >0.05). Occlusal walls in enamel, in both groups, exhibited less leakage than the cervical walls in cementum (p <0.01) and Group 1 showed better results than Group 2 in decreasing microleakage at the cementum margins (p <0.05).

Conclusion Based on the results, it was concluded that concave-beveled cavity preparations may reduce but did not totally eliminate microleakage at the cementum margins of Class V composite resin restorations in primary teeth.

Keywords Adhesion; Microleakage; Primary teeth.

Introduction

In paediatric dentistry there is an increasing demand for the aesthetic benefits of adhesive dentistry [Atash and Abbeele, 2004] with more conservative cavity preparation and increased aesthetic properties being strong reasons for using resin-based composite restorations (RBCs). However, failure of RBCs in primary teeth is still a common problem in paediatric dentistry, due in part to the fact that RBCs are technique sensitive [Casagrande et al., 2005], the lack of cooperation in small children, leading to inadequate tooth isolation and subsequent higher incidence of marginal leakage [Atash and Abbeele, 2004]. Microleakage is defined as the “clinically undetectable passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative material applied to it” [Kidd, 1976]. Studies have shown that marginal percolation can be caused by polymerisation shrinkage, thermal changes, and water absorption of the materials, which result in gap formation at the tooth/restoration interface [Kemp-Scholte and Davidson, 1988; Carvalho et al., 1996; McCoy et al., 1998; Campanella and Meiers, 1999; Ferracane, 2005]. It may lead to negative clinical consequences such as postoperative sensitivity, discoloration of the restoration, recurrent caries, and damage to the pulp [Owens et al., 1998; Mjör et al, 2002; Ferracane and Mitchem, 2003; Yazici et al., 2003].

The advent of the acid-etch technique to increase bond strength to enamel, introduced by Buonocore in 1955, has proven effective in reducing but not eliminating microleakage at the margins of restorations [Munro et al., 1996; Swift et al., 2001]. Nonetheless, bonded interfaces are not yet perfect and confidence in their long-term durability is not complete. Gingival margin continues to be a significant source of microleakage and dentistry continues to seek improved restoration margins and material properties [Swanson et al., 2008].

To achieve clinical success for Class V cervical restorations with a gingival margin in dentin and cementum, marginal leakage must be minimised or eliminated [Fitchie et al., 1995; Starr, 2006]. Studies have been carried out to investigate various restorative techniques [Santini and Mitchell, 1998; Santini et al.,
Bevelled enamel margins have been advocated to decrease microleakage of cervical restorations [Opdam et al., 1998; Owens et al., 1998; Hoelscher et al., 2000] and provide more prepared enamel surface area where exposed enamel rod ends are available for acid conditioning and subsequent bonding. A bevel increases bonding to the enamel rod ends without overcontouring the restoration [Swanson et al., 2008]. The question then arises whether a cavosurface bevel plays a role in providing an improved seal around gingival dentin/cementum margins of Class V RBCs. Furthermore, little work has been reported on the use of bevelled margins on primary tooth enamel [Atash and Abbeele 2004; Casagrande et al 2005; Swanson et al 2008].

Studies evaluating the primary enamel have reported the presence of a 20- to 100-µm thick prismless or aprismatic zone at its surface, though the nature of this zone may vary in any individual tooth [Ripa et al., 1966; Kodaka et al., 1989]. Within the prismless zone, all the crystals are aligned parallel to each other and perpendicular to the surface, the zone being generally more highly mineralised due to the parallel nature of the crystals and the lack of prism boundaries [Kodaka et al., 1989]. The difference in the enamel structure of primary teeth suggests that the results and conclusions of bonding experiments on permanent enamel should not be applied directly to primary enamel and that experimental testing should be carried out separately on primary teeth [Swanson et al., 2008].

The purpose of this study was to investigate in vitro, by using primary molars, the effect of concave and straight-bevelled cavity preparations on the marginal leakage of Class V RBCs.

Materials and methods

Twenty non-caries primary first and second, upper or lower molar teeth, obtained from the Human Teeth Bank of the School of Dentistry, Fluminense Federal University, Niterói, Brazil were included in the study. These had been extracted for orthodontic reasons or because of physiological advanced root resorption. Immediately after the extraction, teeth were rinsed, stored and sterilised in 2% formaldehyde solution at pH 7.0, for 30 days at room temperature. The teeth were cleaned with slurry of pumice and water with a rubber cup in a low-speed handpiece for 15 seconds and stored refrigerated at 4°C in distilled water until preparation.

The experimental design of the study is shown in Figure 1.

Cavity preparation

Two standardised class V cavities (4 mm in width x 3 mm in height x 2 mm in depth) were prepared in the cervical third of the buccal (occlusal and gingival margins in enamel) and lingual (occlusal margin in enamel and gingival margin in cementum) surfaces of the teeth with a No. 330 tungsten carbide bur (KG Sorensen™, Barueri, SP, Brazil) under air-water spray using a high-speed dental handpiece. Cavity standardisation was obtained by means of a digital caliper rule (Mitutoyo, Kyoto, Japan). The length of the bur (2 mm) was used as a guide for the cavity depth. New burs were used after every five preparations. The teeth were then randomly assigned to two groups of 10 teeth each (20 preparations). In Group 1, a 1 mm concave bevel was
made on the occlusal and gingival margins with a high-speed No. 04 tungsten carbide bur (KG Sorensen™, Barueri, SP, Brazil) and in Group 2, a 1 mm straight bevel was made on the occlusal and gingival margins with a high-speed No. 556 tungsten carbide bur (KG Sorensen™, Barueri, SP, Brazil). The preparations were pumiced with a rubber cup in a slow-speed handpiece and then washed thoroughly with water.

**Cavity restoration**

The prepared surfaces were etched with 37% phosphoric acid gel (Dentsply/Caulk Ind. e Com. Ltda., Petrópolis, RJ, Brazil) for 15 seconds, rinsed with water spray for 30 seconds and gently air dried. The teeth were incrementally restored in approximately three 1-mm increments with Filtek™ Z 350 composite resin (3M ESPE Dental Products Division, St. Paul, MN, USA), using Adper™ Single Bond 2 (3M ESPE Dental Products Division, St. Paul, MN, USA) as the enamel/dentin adhesive. The adhesive was light cured for 10 seconds with an Optilux 401 (Demetron Research Corp., Danbury, CT, USA) visible-light-curing unit. A preliminary increment, about 1 mm thick was set horizontally in the cervical wall using a plastic instrument. The second and third increments were placed diagonally in the cavity. Each increment was cured for 40 seconds with an Optilux 401 (Demetron Research Corp., Danbury, CT, USA) visible-light-curing unit. All materials were handled according to the manufacturer’s instructions.

After storing in distilled water at 37°C for 24 hours in individual plastic bottles, the restorations were finished and polished, using a high-speed No. 7901 finishing bur (KG Sorensen™, Barueri, SP, Brazil) and Sof-Lex XT extra thin discs (3M ESPE Dental Products Division, St. Paul, MN, USA) of decreasing abrasiveness with a continuous water spray.

**Silver penetration**

Samples were thermocycled 5,000 times between water baths held at 5°C and 55°C for 15 seconds at each temperature with a dwell time of 15 seconds and a 15-second transfer time. After thermocycling, the teeth were covered with 2 coats of nail polish up to approximately 1 mm of the periphery of each restoration. Once dry, the teeth were placed in a freshly prepared 50% solution of silver nitrate for 24 hours and kept in darkness. They were then rinsed in tap water at room temperature for one minute and immersed for eight hours in photodeveloping solution [Sano et al., 2008; Atash and Abbeele, 2004; Swanson et al., 2008; Khier et al., 1995]. Then specimens were rinsed in tap water to remove the solution.

The teeth were embedded in acrylic resin (L.D. Caulk/Dentsply International, Milford, DE, USA) and 1 mm thick samples were prepared by sectioning longitudinally in a buccolingual direction through the centre of the restorations using a water-cooled diamond disc (KG Sorensen™, Barueri, SP, Brazil).

Each surface was subsequently examined using a x40 stereoscopic microscope (Mitutoyo, Kyoto, Japan). The occlusal and gingival margins were qualitatively evaluated separately and scored for silver penetration according to the following criteria [Salim et al., 2005]:

- 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.

Two experienced evaluators were calibrated in using this rating scale and independently scored each specimen. Evaluators were blinded as to which group was being evaluated. Discrepancies were rescored to reach consensus. The interexaminer reliability was at the same level (Kappa = 0.9, p<0.01).

**Statistical analysis**

The results obtained were compared using non-parametrical statistical analysis (Mann-Whitney U test and Kruskal-Wallis H test) followed by a Multiple Comparison test (Dunn’s test) to identify significant differences between the two groups. Statistical software (version 15.0, SPSS Inc., Chicago, IL, USA) was used and results were considered significant for p<0.05.

**Results**

The microleakage scores are summarised in Figures 2 and 3.

No statistically significant differences were found between the groups with either concave or straight bevels at the enamel margins (Z = 1.96; H = 4.39; p>0.05) (Fig. 2). Dunn’s test indicated that significant differences existed in the overall comparison of microleakage scores between enamel and cementum surfaces (p<0.01). For both cavosurface bevels used, microleakage was significantly greater in cementum surfaces than in enamel surfaces (H = 55.51; p<0.05) (Fig. 3). Comparing the two groups, Group 1 (concave bevel) showed decreasing microleakage at the cementum margins compared to Group 2, though microleakage was not completely eliminated.

**Discussion**

Restoration of Class V cervical lesions involves replacing tooth structure lost through wear, erosion, and/or the carious process [Sidhu and Henderson, 1992]. These lesions can have margins in dentin or cementum as well as enamel, and numerous restorative techniques have been described in the literature in an effort to achieve a reliable gingival seal along the tooth/ restorative material interface [Nozaka et al., 1999; Atash and Abbeele, 2004; Swanson et al., 2008; Khier et al., 1995].
and Hassan, 2011]. To date, few microleakage studies have provided information concerning dentin bonding with a gingival (dentin/cementum) bevel in primary teeth [Atash and Abeele, 2004; Swanson et al., 2008].

According to Hembree [1980], beveling the enamel margins of a Class V RBCs is effective in providing an increase in surface area for etching, removing the prismless layer of surface enamel, facilitating the finishing procedure and achieving a more aesthetic restoration, completely exposing the ends of the enamel rods for resin attachment and thus restorative bonding, and decreasing microleakage.

The lower scores of dye penetration at the enamel margins in this study (Fig. 2, 3) with either concave or straight bevel compared with the gingival cemental margins are consistent with previous studies in primary and permanent teeth [Lee and White, 1998; Owens et al., 1998; Nozaka et al., 1999; Swanson et al., 2008; Khattab et al., 2006]. These results also lend support to the statement that “the resin-bond is not strong enough to withstand the polymerisation contraction forces in spite of the use of the new dentin adhesives” [Sindhu and Henderson, 1992]. On the other hand, some authors [Atash and Abeele, 2004; Santini et al., 2004; Bagheri and Ghavamnasiri, 2008] reported no significant difference in microleakage between bevelled and non-bevelled margins in primary and permanent enamel.

Zidan et al. [1987] evaluated the effects of dentinal bonding agents on marginal gaps in Class V resin restorations in permanent teeth and observed that the frequency of gap occurrence followed a consistent pattern for most of these agents. The lowest frequency was at the enamel occlusal locations, gradually increasing toward the dentin, with the highest frequency at the gingival locations, which was the same found in the present study using primary teeth, mainly in the straight-bevel group.

The difference of marginal leakage scores between the two groups found in this study was also observed by other authors [Futatsuki et al., 1990; Nozaka et al., 1999; Khattab et al., 2006; Swanson et al., 2008]. These authors obtained a better marginal seal with a concave bevel than with either a straight bevel or non-bevel (butt joint) margins by thermal and load cycling of the specimens.

Mandras et al. [1991] suggested that, in the evaluation of microleakage in laboratory studies, restored teeth should be subjected to both thermal and occlusal stresses so that intra-oral conditions are more closely simulated. Moreover, Barnes et al. [1993] comparing the occurrence of microleakage between Class V resin restorations placed in vivo and in vitro, reported that laboratory microleakage tests of thermocycled resin restorations predict more leakage than that found in clinical restorations. On the other hand, Prati et al. [1994] found that neither thermocycling nor occlusal stresses increased the microleakage of the restorations in vitro. Also Rosales-Leal [2007] observed that thermocycling did not affect the occlusal bonding in Class V resin restorations.

The present study used only thermal stresses to simulate intra-oral environment, and as an in vitro study, it has its limitations as not all variables can be reproduced, such as pH of the oral cavity, bacteria, diet, salivary content and flow, and medications. Also mechanical stresses of function and enamel rod orientation may influence marginal integrity and adhesive bonding ability [Swanson et al., 2008], which were not incorporated in the study.
Several microleakage studies [Barnes et al., 1994; Atash and Abbeele, 2004; Rosales-Leal, 2007; Bagheri and Ghavamnarisi, 2008; Chandra et al., 2011] employed both the buccal and lingual surfaces of teeth in their methodology, as was done in this study. Barnes et al. [1994] compared microleakage of buccal and lingual tooth structure and stated that the experimental technique of using both surfaces appears to introduce no positional variables in an in vitro research design. Thus, these surfaces can be prepared and restored in the same manner, since buccal and lingual enamel, dentin, and cementum respond in a similar manner with respect to microleakage.

The results in the present study indicate that there was good adhesion and marginal sealing with the adhesive at the occlusal margins when a bevel was prepared to make the bonding surface as extensive as possible. Swanson et al. [2008] also observed that the presence of a marginal bevel significantly reduced microleakage in primary and permanent enamel (70% overall), regardless of the type of adhesive used. This would indicate that bevelling the enamel margins of primary teeth may produce a higher degree of clinical acceptability and may be the configuration of choice for the Class V RBCs in primary enamel. On the other hand, no treatment was successful in preventing the penetration of dye at cervical (cemental) margins, in spite of the better results with the concave bevel group.

The lower degree of microleakage exhibited by all occlusal margins in the present study compared to cervical margins can be explained by the presence of enamel at these walls and margins which provided a stronger adhesive bond that has overcome the weaker dentin bond at the gingival wall. The gingival wall is formed by dentin, which consists of minerals, organic compounds (mainly collagen fibers), and water [Khier and Hassan, 2011]. Another factor is the adhesive itself: the chemical composition plays an important role in achieving a strong, durable, and a biological, compatible bond [Mjör at el., 2002]. After phosphoric acid treatment, there is a deep demineralization front in which the collagen network is exposed, dentin tubules are open, and water content is increased. The adhesive have to infiltrate the exposed collagen, replace the water, and seal the tubules, which turns sealing complicated [Rosales-Leal, 2007].

The interaction of water and specific enzymes with the hydrophilic resins and the collagen fibrils additionally seem to cause long-term breakdown of the transitional layers. Further improvements to refine the transitional layer to improve its adaptation to the intact tissue and enhance its long term resistance to hydrolysis and breakdown still remain central challenges for future research [Vaidyanathan and Vaidyanathan, 2009].

The adhesive’s acidity may also affect the initial enamel etch, thus influencing marginal integrity and bonding ability. Studies have shown that adhesives with low pH demineralize the smear layer and tooth structure improving the marginal sealing [Ibarra et al., 2002; Atash and Abbeele, 2004; Perdigão et al., 2006; Rosales-Leal, 2007]. The adhesive used in the present study has high pH (pH= 4.7), which may interfere in the dentin bonding, if the time required to allow complete diffusion of the adhesive into the denatured dentin is not respected, thus adequate penetration may not be achieved. However, the effects of acidity on bonding ability in primary enamel are still inconclusive [Swanson et al., 2008].

It is well known that primer and adhesive resin may incompletely penetrate the demineralized dentinal collagen layer after etching in total etching bonding systems. This discrepancy between depth of dentin demineralization after the acid-etching procedure and depth of resin infiltration facilitates the formation of voids or microporous zones underneath and within the hybrid layer detectable by silver nitrate [Vaidyanathan and Vaidyanathan, 2009], which was the isotope used in the present study. Microleakage that facilitates bacterial percolation occurs only when the gaps at the margins are 10–20 µm wide. But Sano et al. [1995] observed silver nitrate tracer penetration into the hybrid layer even when they detected no gaps at the margins. The authors also observed that the relatively smaller tracers (silver) penetrated the full thickness of the hybrid layer in some areas, and into the adhesive resin. They called it “nanoleakage”, which occurred through 20–100 nm gaps at the margins. Several investigators have since evaluated nanoleakage expression in different adhesive systems in the last decade [Vaidyanathan and Vaidyanathan, 2009]. Distinctly different types of nanoleakage patterns (e.g., spotted, reticular, water-treeing) have been reported by TEM and SEM studies. Hydrolytic breakdown of the dentin–restoration bond has been attributed to the mechanism of nanoleakage expression in the bonded interface [Vaidyanathan and Vaidyanathan, 2009]. This phenomenon may have occurred in this study.

Since these results are in vitro data, and it is difficult to extrapolate them directly to the clinical situation, definite conclusions should not be drawn until further in vivo studies are completed.

Conclusions

Within the limitations of this study, the following conclusions may be drawn.

- In primary teeth, cavity preparations with margins in enamel exhibited less microleakage than margins placed in cementum, irrespective of type of bevelling.
- Considering margins in cementum, concave bevelled margins showed less microleakage compared to straight bevelled margins, though microleakage was not eliminated completely.
Microleakage in resin restorations

References


