# Microleakage of adhesive resin systems in the primary and permanent dentitions

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## Abstract

**Purpose:** The purpose of this study was to compare the in vitro microleakage of fourth-generation filled and unfilled adhesive resin systems with fifth-generation filled and unfilled adhesive resin systems in both primary and permanent teeth.

**Methods:** Eighty extracted or exfoliated human noncarious teeth (40 primary and 40 permanent) were assigned to each of 8 groups. Groups 1, 3, 5 and 7 were primary teeth, and groups 2, 4, 6 and 8 contained permanent teeth. Groups 1 and 2 were bonded with Optibond Fl (Kerr), groups 3 and 4 with Scotchbond Multipurpose (3M), groups 5 and 6 with Optibond Solo Plus (Kerr) and groups 7 and 8 with Single Bond (3M). All teeth received a Class V cavity preparation, and the cavosurface margins were placed entirely in enamel. They were then restored with TPH Spectrum Shade A1 (Dentsply Caulk). All teeth were thermocycled, stained with basic fuchsin, sectioned and viewed under the microscope. Measurements were recorded in absolute millimeters and relative grades as judged by 2 evaluators.

**Results:** No significant difference in microleakage was observed between fourth- and fifth-generation adhesive resin systems, whether filled or unfilled, or applied on primary or permanent teeth. Significant differences were found in the amount of microleakage at the gingival and occlusal surfaces in all groups. One-bottle, fifth-generation adhesive resin systems permit easier application with the same effectives as the 2-bottle, fourth-generation systems.

**Conclusions:** One-bottle, fifth-generation adhesive resin systems permit easier application with the same effectiveness as the 2-bottle, fourth-gerenration systems. (*Pediatr Dent*. 2002;24:587-593)

KEYWORDS: BONDING, ADHESIVE RESIN, MICROLEAKAGE

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## Dentin adhesives

Dentin bonding was first reported in 1956 and focused on chemical adhesion to dentin.[1] Clinical studies showed these agents to have bond strengths of only 2 to 3 MPa and retention rates of only 50% after 6 months.[2]

Second-generation adhesive resin systems were introduced in the early 1980s and were also known as phosphate bonding systems because of their use of a phosphate group to bond to the calcium in the mineralized tooth. The major change in second-generation agents was the use of Bis-GMA replacing dimethacrylate. In 1992, Barkmeier and Cooley found second-generation agents to have bond strengths as high as 6 to 7 MPa with Prisma Universal Bond.[3] Most agents of this generation left the smear layer intact, while some had mild cleansers designed to minimally alter the smear layer.

Third-generation agents were considered more technique sensitive and time consuming due to the fact that most agents of this generation contained conditioner, primer and adhesive; however the bond strength improved.[4] These agents were based on the removal of the smear layer to produce micromechanical interlocking for bond strength. Many of these agents contained both hydrophilic and hydrophobic agents, which interacted with the dentin to create a hybrid layer and mechanical interlocking as opposed to purely chemical adhesion.[5]

Fourth-generation agents use a similar bonding mechanism but have distinct advantages of reduced technique sensitivity and improved performance under moist conditions.[5] Dentin bonding relies on micromechanical interlocking of the fibrillar collagen exposed by acid etching. Overetching or overdrying the collagen can lead to denaturation or collapsed fibrils resulting in decreased bond strength.[6,7] Scotchbond Multi-Purpose was found in an in vitro study to have bond strength similar to that of enamel.[8] In another study, Scotchbond Multi-Purpose was found to have higher shear bond strength and lower microleakage in sealants on primary teeth than Syntac or Optibond Dual Cure.[9] Optibond Fl was demonstrated to have less microleakage compared to its third generation predecessor.[10] Yap et al found that composite restorations bonded with Scotchbond Multi-Purpose had significantly less microleakage at the occlusal margin than restorations bonded with Gluma Bond in thermocycled specimens. However, Scotchbond Multi-Purpose did have more leakage at the cervical margin than Gluma Bond.[11]

Fifth-generation agents were introduced with the idea of simplifying the application of dentin treatment and bonding with the use of only 1 bottle. However, most of these systems still require prior acid etching and some require multiple applications of the adhesive.[9] The results of limited studies undertaken so far on fifth-generation agents are conflicting. Some exhibit weaker bond strengths in the fifth-generation compared to the fourth-generation, while others demonstrate improvement.[10-12] This variation may be due to technique factors, particularly the importance of achieving a proper dentin moisture level.[9] Pilo and Ben-Amar studied 2- bottle, fourth- and 1-bottle, fifth-generation dentin bonding agents on permanent teeth and found no significant difference in microleakage comparing the generation of the agent, the manufacturer and the location of the cavity margins.[12]

## Primary vs permanent teeth

Dentin bonding studies performed on primary teeth have shown lower bonding strength in the primary teeth when compared to the permanent teeth.[13,14] This may be due to the increased thickness of the hybrid layer in primary teeth and the consequent decreased penetration of adhesive resin into the dentin.[15] The composition and micromorphology of dentin in primary teeth is not fully understood. However, it is known that primary and permanent dentin do differ in composition and structure. Permanent dentin has been found to be denser and more highly mineralized than primary dentin.[16]

In 1989, Wilson and Beynon demonstrated that, when compared with their permanent analogues, primary teeth show decreased mineralization. They also found that permanent teeth had a mineralization gradient, with greater mineralization near the occlusal portion of the tooth and reduced mineralization at the cervical portion of the tooth. This gradient also existed in primary incisors and canines, but not in primary molars.[17] Theuns had previously reported this gradient in premolars in 1983.[18] The findings of Wilson and Beynon were confirmed by Mjör and Nordahl in 1996.[19] Additional studies revealed that primary dentin has a lower concentration and smaller size of dentinal tubules than permanent dentin.[20] Current dentin adhesives depend on the permeation of hydrophilic resin into chemically conditioned dentin (hybridization). Hybridization can be affected by dentin thickness, the degree of demineralization, and pretreatment regimens among other factors. These differences between primary and permanent dentin may lead to different bond strengths.[15,21]

## Filled vs unfilled

All composite resins undergo shrinkage during polymerization, resulting in stresses at the tooth/restoration interface. These stresses can lead to formation of microgaps as the restoration is "pulled away" from the tooth, resulting in microleakage.[22-24] While unfilled resins are no longer used as restorative materials, they are still used as dentin adhesives. It is well established that filler content and particle size contribute significantly to the physical properties of resins.

Swartz et al, in 1985, demonstrated that filled resins exhibit significant improvement in wear resistance over unfilled resins.[25] They also found that increased filler levels resulted in increased hardness, compressive strength and stiffness as well as a decrease in water sorption.

In 1989, Crim showed that, while highly-filled composites may have higher bond strengths, they also tend to have greater microleakage than less viscous microfilled resins. Additionally, the microfilled resins have higher water sorption values, which lead to more expansion of the resin to counteract the polymerization shrinkage reducing microleakage.[26]

In addition to increased water sorption, unfilled resins have greater ability to flow under the stress of polymerization than filled resins. This ability to flow compensates for the polymerization shrinkage and again reduces the formation of microgaps between the dentin and the restoration.[22] The ability to flow is strongly influenced by the type of composite and the configuration of the cavity. When the ratio between the restoration's bonded surface and the free bonded surface (known as the "C" factor) is 0.5 or less, much of the polymerization shrinkage is accounted for by flow, but when the C factor is much greater, the compensation by flow is significantly reduced. [27] Class V and Class I preparations have high C factors indicating they have a high stress component. This high C factor is the reason for using Class V preparations to test the efficacy of the filled vs unfilled fourth- and fifth-generation dentin adhesive systems.

## Microleakage

A key test of dental restorative materials is their marginal integrity along the tooth restorative interface. The clinically undetectable passage of bacteria, fluids, molecules, or ions between the cavity wall and the applied restorative material has been defined as microleakage.[28] The inability of a restorative material to adapt or adhere tightly to dental hard tissues is what creates the gaps allowing microleakage to occur. Some of the sequelae of microleakage include tooth discoloration, accelerated deterioration of restorative materials, recurrent caries, pulp pathology and postoperative tooth sensitivity.[29,30] There are many techniques to test microleakage. These include the use of compressed air, bacterial studies and chemical and radioactive tracers.[31]

The purpose of this study was to compare the in vitro microleakage of fourth-generation filled and unfilled dentin bonding systems to fifth-generation filled and unfilled adhesive resin bonding systems in both primary and permanent teeth.

## Methods

### Tooth selection

Forty extracted permanent molars and 40 extracted or exfoliated primary teeth (anterior and posterior primary teeth were equally distributed among the groups) were obtained from the University of Southern California and private practitioners. All of the teeth in this study had at lease 1 surface free of carious lesions. Any lesions on the adjacent surfaces were minimal and did not extend to the prepared surface.

The teeth were stored in 0.5% Chloramine-T solution, a mild disinfectant that does not alter enamel or dentin collagen matrix.[32]

Once all teeth had been collected, they were thoroughly rinsed and the root surfaces were scaled to remove any remaining tissue.

### Randomization into groups

The teeth were then mounted individually in custom rings and then arbitrarily assigned numbers from 1 to 80 (1-40 for primary teeth, 41-80 for permanent teeth). Utilizing a simple random design, 10 specimens were assigned to each of 8 groups:

- group 1—fourth-generation, filled, primary teeth, Optibond Fl (Kerr);
- group 2—fourth-generation, filled, permanent teeth, Optibond Fl (Kerr);
- group 3—fourth-generation, unfilled, primary teeth, Scotchbond Multipurpose (3M);
- group 4—fourth-generation, unfilled, permanent teeth, Scotchbond Multipurpose (3M);
- group 5—fifth-generation, filled, primary teeth, Optibond Solo Plus (Kerr);
- group 6—fifth-generation, filled, permanent teeth, Optibond Solo Plus (Kerr);
- group 7—fifth-generation, unfilled, primary teeth, Single Bond (3M);
- group 8—fifth-generation, unfilled, permanent teeth, Single Bond (3M).

### Cavity preparation

All teeth were then prepared with a high-speed handpiece and a 330 bur. One Class V preparation in enamel, with rounded outlines and 3 mm width, 2 mm height, and 2 mm depth, was made on the buccal or lingual surface of each tooth. After every fifth cavity preparation, a new bur was utilized.

### Placement of adhesive and composite

After preparation, each tooth was bonded according to the manufacturer's instructions. The teeth were then restored with TPH composite from Dentsply, shade A1. By using a composite from a company other than 3M or Kerr, any affinity of the composite to a specific adhesive system was eliminated. The restorations were then light cured for 40 seconds and polished with the Sof-Lex finishing and polishing system by 3M.

### Thermocycling

All specimens from within each group were removed from their mountings, wrapped in gauze, and placed in a bag tagged with the group number. The teeth were then thermocycled in distilled water at between 5 and 55 °C for 1000 cycles with a dwell time of 30 seconds and a draining time of 10 seconds between cycles. After thermocycling, the apices of all teeth were sealed with Fuji IX Glass Ionomer Restorative Cement to prevent apical leakage. Two layers of nail varnish were placed within 1 mm of the margins of all restorations. The specimens were then immersed in 0.5% aqueous basic fuchsin solution for 12 hours.[32-34] After the 12 hours, all teeth were rinsed in distilled water and mounted in clear acrylic resin in custom rings. The teeth were labeled by group number and then sectioned into 3 occlusoapical sections with a diamond saw (4 in X 0.012 in medium grit), yielding 8 interfaces for examination (Fig 1).

### Measurements

With a Unitron TMD 6369 microscope (Unitron Instrument Company) linked to a Microde II (Boekler Instruments) at 200X magnification, the extent of microleakage, in millimeters, was measured. Two independent evaluators blind to the conditions of the study examined the cut surfaces. Eight measurements, 4 at the occlusal and 4 at the gingival margin, were taken for each specimen. All measurements were taken from the junction of the tooth-restoration interface to the first point of termination of the dye. The average amount of microleakage was calculated as well as the mean values and relative

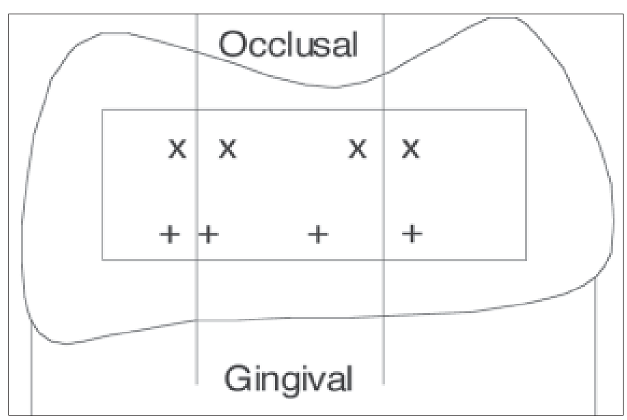


Fig 1. Eight interfaces for examination
x indicates occlusal points of measurement
+ indicates gingival points of measurement

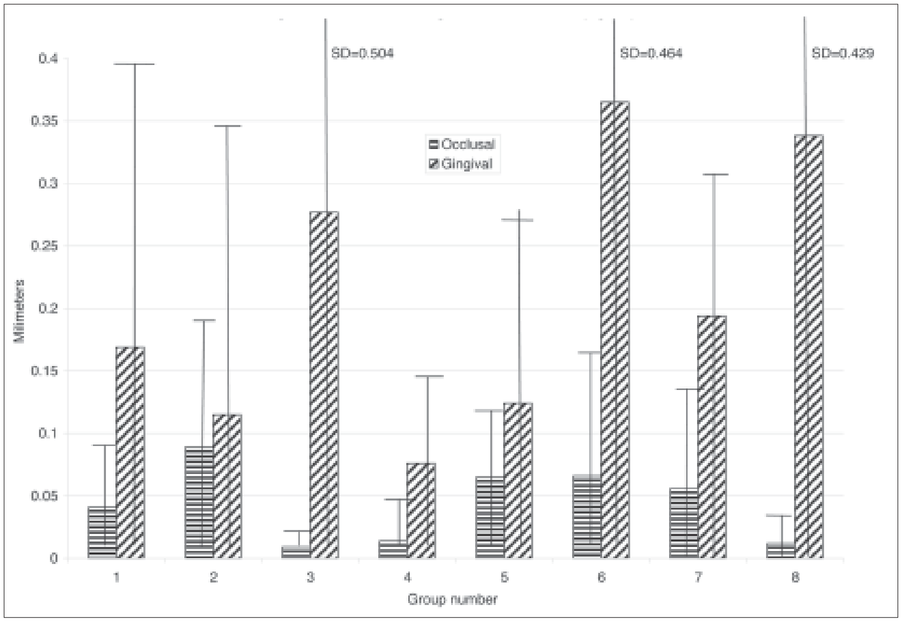

Fig 2. Mean microleakage measurement by group


Fig 3. Sectional view representative of samples that were judged to have no microleakage


Fig 4. Sectional view representative of samples that were judged to have microleakage

percentages of each group. Measurements were recorded in both absolute millimeters and grade as judged by the 2 evaluators. Grades were assigned as follows:

- grade 1—no microleakage;
- grade 2—microleakage extending up to one-third the depth of the preparation;
- grade 3—microleakage extending between one-third and two-thirds the depth of the preparation;
- grade 4—microleakage extending between two-thirds and the entire depth of the preparation.

### Statistical analysis

Spearman correlation coefficients ($r_s$) were used to check for consistencies in microleakage measurements between the 2 evaluators. The means of the 2 raters' measurements were used to do a 1-way ANOVA testing if measurements differed by group. Fisher's exact tests were performed to test for significant differences in grade by group. Analyses on grade were done based on the highest grade provided by either evaluator.

Further analyses involved calculating an overall mean combining all 4 sections for the occlusal and gingival of each of the teeth by group. Multiple regression analyses were performed to find the best possible predictor of microleakage measurements by site (occlusal vs gingival ), type of tooth (primary vs permanent), and generation of dentin bonding agent (fourth vs fifth). Wald's *P* values were reported for the regression analyses. Interactions were checked for using the partial F-test. All data was evaluated at the 0.05 significance level.

## Results

Moderate to strong measures of association were found between the 2 evaluators of this study (all $r_s$ were greater than or equal to 0.55, *P*=.0001). The correlation coefficient between linear millimeter and relative grade measurements indicated that the 2 methods yielded similar results.

Figure 2 shows the mean occlusal and gingival measurements for each group. The mean microleakage was less than 0.5 mm for the gingival of all groups and less than 0.15 mm for the occlusal surfaces of all groups. Figure 3 is a sectional view representative of samples that were judged to have no microleakage. Figure 4 is a sectional view representative of samples that were judged to have microleakage. No statistical difference was found in mean measurements across the 8 groups using the 1-way ANOVA (all *P*>.05). The mean grade for the occlusal surfaces was less than or equal to 0.4, and for the gingival it was less than 1. There was also no statistical difference found in the grade among the groups (all *P*>.05). The mean grade findings are shown in Figure 5.

Table 1 shows the results of the regression models. The regression models showed that the site of the tooth (occlusal vs gingival) was the only statistically significant predictor of the amount of microleakage (parameter estimate= 0.1567; *P*=.0001). Neither the type of tooth (primary vs permanent; *P*=.6308) nor the generation of the dentin-bonding agent used (*P*=.1447) were statistically significant predictors of the amount of microleakage. No significant interactions were found (*P*>.05).

## Discussion

The goal of this study was to determine if there is a significant difference in the amount of microleakage between fourth- and fifth-generation, filled and unfilled adhesive

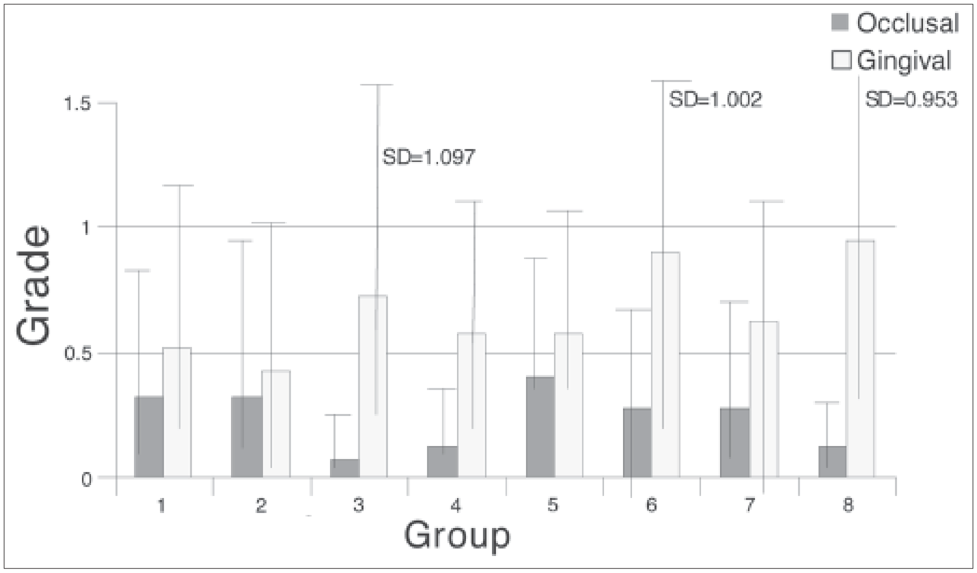


Fig 5. Mean grade by group

**Table 1. Regression Model**

| Variable | Parameter estimate | *P* value |
|---|---|---|
| Site on tooth (occlusal vs gingival) | -0.1567 | .0001 |
| Type of tooth (primary vs permanent) | 0.0176 | .6308 |
| Generation of bonding agent (fourth vs fifth) | 0.0536 | .1447 |

resin systems in primary and permanent teeth. This was done by evaluating the extent of microleakage present along the tooth restoration interface in similarly prepared teeth. Four different adhesive resin systems from 2 manufacturers were selected and tested.

According to the results of this study, there is no statistically significant difference in the amount of microleakage between fourth- and fifth-generation, filled or unfilled dentin bonding systems. In addition, no difference was found between permanent and primary teeth using any of the 4 bonding systems. There was significantly less microleakage at the occlusal than at the gingival region in all groups.

The advent of fifth-generation, 1-bottle systems was to improve performance while simplifying application. In terms of clinical use, the fifth-generation agents required fewer steps and were, in fact, easier to apply. However, the results of this study indicate there is no difference between fourth- and fifth-generation agents in microleakage. These results support the findings of previous studies, which have shown no difference in microleakage in enamel margins comparing fourth- and fifth-generation dentin bonding systems in permanent teeth.[12]

Highly filled composites have been found to increase bond strengths, but microleakage has been found to be higher because the increased stiffness leads to the formation of microgaps with polymerization shrinkage. Microfilled resins have increased water absorption and greater ability to flow under stress than the highly filled resins. For these reasons, microfilled resins have been found to have less microleakage than their highly filled counterparts.[22,26] In this study, the results indicated no significant difference whether the adhesive was filled or unfilled.

Previous investigations, including those by Bordin-Aykroyd et al in 1992 and Nor et al in 1995, found significant differences in the bonding strength and the micromorphology between primary and permanent teeth; however, little investigation of microleakage has been done.[13,15] It has been shown that permanent teeth are more mineralized than primary teeth, which would lead to the assumption that a better seal would be formed in permanent teeth. Other investigators have also recommended reducing the etching time of primary dentin to avoid increasing the thickness of the hybrid layer in primary teeth.[14] In this study, the primary and permanent teeth were all restored according to the manufacturer's guidelines which do not specify different etching times for primary or permanent teeth. The results of this study support the manufacturers' recommendations of treating primary and teeth in the same manner.

The fact that the majority of the microleakage found in this study was at the gingival portion of the preparation may be a due to a difference in the quality of the tooth structure between the occlusal and gingival aspects of the enamel. Avery et al determined that the enamel in both human and monkey teeth is harder at the cusp than at the cervical portion of the tooth.[35] Crabb and Darling found that the cuspal enamel was more uniformly mineralized than the cervical enamel.[36] In 1979, Glick found that mineralization begins at the dentin enamel junction in the cusp of the tooth and then extends in a cervical and peripheral direction such that the surface layer of enamel at the cervical portion of the tooth is the last to be mineralized.[37] Theuns found a clear gradient in mineralization from the occlusal to the cervical in premolar teeth in 1983.[38]

Wilson and Beynon confirmed this gradient in permanent teeth as well as in primary incisors and canines.[17] However, they determined that there was no occlusocervical mineralization gradient in primary molar teeth. Nonetheless, this difference in mineral content may account for some of the difference in microleakage between the occlusal and cervical margins in this study. Previous microleakage studies have found significant differences in the amount of microleakage at enamel vs cementum margins.[10] While all margins in this study were in enamel, this further supports the conclusion that mineralization of enamel towards the gingival aspect has a definitive effect on microleakage.

Further studies testing these materials in vivo are warranted to determine whether the amount of microleakage is the same as the in vitro study and whether the observed amount of microleakage, if present, is clinically relevant.

## Conclusions

1. No significant difference in microleakage was observed between fourth- and fifth-generation dentin bonding systems, whether filled or unfilled, or applied onto primary or permanent teeth.
2. Significant differences were found in the amount of microleakage at the gingival and occlusal surfaces in all groups.
3. One-bottle, fifth-generation dentin-bonding systems permit easier application with the same effectiveness as the 2-bottle, fourth-generation systems.

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