the Journal of CONTEMPORARY DENTAL PRACTICE
at www.thejcdp.com
Volume 8 Number 2 February 1, 2007

Gap Formation between Different Cavity Walls and Resin Composite Systems on Primary and Permanent Teeth

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Abstract

Aim: The aim of this study was to compare the effectiveness of five self-etching and etch-rinse dentin-bonding agents in achieving a gap-free adaptation between the restorative material and the dentin in primary and permanent teeth.

Methods and Materials: Gaps located at the restoration dentin interface were evaluated using scanning electron microscopy (SEM).

Results: There were more gaps on the corner of the cavities, but no significant difference was detected between different cavity walls (p>0,05). Statistical results of the SEM analysis revealed fewer gaps in the restorations made with self-etching dentin bonding agents than etch-rinse agents at the restoration-dentin interface in both primary and permanent teeth.

Conclusion: Self-etching bonding systems were preferable in primary and permanent teeth according to the results of this study. However, further studies should be conducted to determine a favorable strategy to eliminate the gaps on the corners of cavities and maintain a gap-free adaptation between resin composite and tooth structure.

Keywords: Gap formation, resin composite systems, primary and permanent teeth

Citation: Tulunoglu O, Ulker AE. Gap Formation between Different Cavity Walls and Resin Composite Systems on Primary and Permanent Teeth. J Contemp Dent Pract 2007 February;(8)2:060-069.

Introduction

Clinical use of composite and other esthetic tooth-colored materials has increased substantially over the past few years as a result of improvements in the formulation and simplification of bonding procedures, increased esthetic demands by patients, and the decline in amalgam usage arising from the fear of mercury toxicity.[1,2]

Polymerization shrinkage of resin composites generates stress between the bonded restoration and tooth structure and continues to be the major antagonist to durable adhesion of resin.[3,4] Perfect marginal adaptation guarantees gap-free margins and prevents microleakage, recurrent caries, pulpal irritation, and is important for the long-term clinical success of adhesive resin restorations.[5,6] A simple method to prevent incomplete resin infiltration into the collagen network of tooth structure is to avoid its unprotected exposure. This can be achieved by treating the enamel and dentin with acidic self-conditioning monomer solutions instead of employing a conventional total-etch procedure.[7] Self-etching primer systems are considered to be easy and reliable procedures to achieve the best-conditioned surface for bonding.[8]

Self-etching systems have been suitable as an alternative to conventional phosphoric acid etchant in permanent enamel and dentin.[9] The use of self-etching systems save time and are less sensitive because they do not require separate acid-etching and rinsing steps and are simply dried with air.[10] Although self-etching systems possess a higher pH than phosphoric acid resulting in less conditioning capacity, they are reported as being capable of producing strong bonding in ground permanent enamel surfaces.[11]

Current restorative techniques rely on bonding to the mineralized structures of the primary and permanent teeth. It is known both dentitions have similar compositions, however, some differences in terms of morphology and mineral content have been well documented in the literature.[12] According to Johnsen[13], primary teeth are less mineralized than permanent teeth and the primary enamel and dentin are also thinner in comparison with permanent teeth. The morphological structure of the intact primary enamel surface is different from that of the underlying middle enamel layer.[14] The intact enamel surface is prismless, hypermineralized, and contains more inorganic material than ground enamel.[12] In spite of such differences parameters established for the preparation of an appropriate dental substrate for bonding procedures have been extensively studied in permanent teeth, and the results are merely extrapolated for primary teeth.[13]

The aim of this study was to compare the effectiveness of five self-etching and etch-rinse dentin-bonding agents in achieving a gap-free adaptation between the restorative material and the dentin in primary and permanent teeth.

Methods and Materials

The materials used in this study included two self-etching, two etch-rinse, and one ormocer bonding agent; their contents are summarized in Table 1. Twenty human primary second molar teeth with root resorption and 20 permanent third molar teeth (all teeth were freshly extracted non-carious, non-restored) were used for the study. After extraction, the teeth were cleaned, disinfected with normal saline for ten minutes, and stored in distilled water at 4°C.

Five different experimental groups were used to evaluate different quality levels of the interfacial bond. Each group consisted of four primary second molar and four permanent third molar teeth free of visible defects. Class V conventional 90° butt-joint type cavities with dimensions of 2 mm x 2 mm x 2 mm were prepared so at least 1 mm of enamel remained along the entire cavity margins.

Cavities were prepared on the buccal and lingual surfaces of each tooth using a diamond bur (SS White Burs, Inc, Lakewood, NJ, USA) in a

Table 1. Materials used in this study (two self-etching, two etch-rinse, and one ormocer bonding agent).

Dentin Adhesives	Manufacturer	Principle Ingredients of Bonding Agents	Application Mode of Bonding Agents
Adper Prompt L-Pop	3M ESPE, Seefeld, Germany	**Liquid 1 (Red blister):** Methacrylated phosphoric esters, Bis-GMA, Initiators based on camphorquinone **Liquid 2 (Yellow blister):** Water, 2-Hydroxyethyl methacrylate, Polyalkenoic acid, Stabilizer.	Brush the adhesive onto the entire cavity surface. Massage it in for 15 seconds. Blow air on the adhesive until it becomes a thin film. The surface must have an even shine. Harden the adhesive with a halogen or LED light for 10 seconds. Harden for only 3 seconds if using a laser or plasma light.
Admira Bond	VOCO GmbH, Cuxhaven, Germany	Complex 3-dimensionally curing inorganic-organic co-polymers. Additive aliphatic and aromatic dimethacrylates and acetone.	Etch the prepared cavity with 34.5% phosphoric acid gel (enamel for about 30 seconds dentin for a maximim 15 seconds). Remove gel by suction, rinse, and remove excess humidity. Introduce Micro Tim into bottle dispenser and let the liquid soak. Apply Admira Bond onto prepared surfaces. Let work in for 30 seconds. Disperse with faint air jet. Polymerize with halogen light for 20 seconds.
Prime & Bond NT	Dentsply De Trey Konstanz, Germany	Primer and adhesive Dipentaerythritol penta acrylate monophosphate, Dimethacrylate resins, Acetone Nanofillers (0.007μm, Aerosil Degussa)	Etch enamel with 34% phosphoric acid for 15 seconds rinse with water air-dry. Apply Prime & Bond NT to enamel and dentin for 30 seconds. Gently air dry. Light cure for 10 seconds.
I Bond	Heraeus Kulzer GmbH, Hanau, Germany	UDMA, 4-META, Water, Camphorquinone, Gluteraldehyde, Acetone.	Saturate the micro brush with iBond liquid from either the bottle or single dose vial. Apply 3 consecutive coats of IBond to both enamel and dentin followed by gentle rubbing for 30 seconds. Use gentle air pressure or vacuum to remove the acetone and water solvent. Cure for 20 seconds.
Gluma One Bond	Heraeus Kulzer GmbH, Hanau, Germany	Gluma Conditioner: 20% phosphoric acid, Pyrogenic silica Gluma One Bond: HEMA, UDMA, 4-META, Acetone.	Apply Gluma CPS Conditioner to cavity surface and leave for 20 seconds. Rinse the conditioner and apply a gentle stream of air for 1-2 seconds. Apply Gluma One Bond to the cavity surface. Immediately apply a second coat of Gluma One Bond. Gently spread the adhesive with air stream approximately 5 seconds. If the cavity surface is not shiny, apply additional coats. Light cure for 20 seconds.

high-speed hand piece with a water coolant. All cavosurface margins were located in enamel and were prepared as butt joints without a bevel. The cavity preparations were randomly assigned to five experimental groups (I-V) and were restored with the various bonding systems and composite resins listed in Table 2. Application of the various dentin adhesives and composite resins was made in strict accordance with the manufacturers' directions. Composite resins were applied to the cavities in two layers using the incremental technique, and each was light-cured for 40 seconds using a Polofil Lux Halogen Light Unit (Voco, Cuxhaven, Germany).

Table 2. Two self-etching, two etch-rinse, and one ormocer bonding agent and their respective composite resin material systems.

Test Groups	Brand Name of Adhesive	Solvent	Acid Used for Etching	Type of Adhesive
Group I	Adper Prompt L-Pop-Filtec Z250 Resin Composite	Water	-	Self etching one bottle primer and adhesive
Group II	Admira Bond-Admira Resin Composite	Acetone	34% phosphoric acid	One bottle primer and adhesive
Group III	Prime&Bond NT-Esthet X Resin Composite	Acetone	34% phosphoric acid	One bottle primer and adhesive
Group IV	I-Bond-Venus Resin Composite	Acetone	-	Self etching one bottle primer and adhesive
Group V	Gluma One Bond-Venus Resin Composite	Acetone	20% phosphoric acid	One bottle primer and adhesive

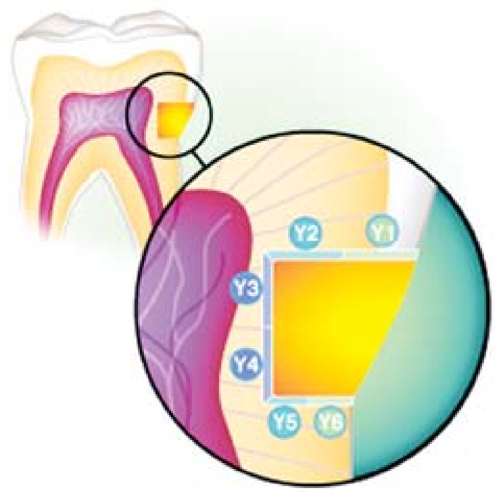


Figure 1. Locational divisions of the cavity walls and section of the restorative material for evaluating the location of gap formation.

Teeth were embedded in self-curing EpoKwick epoxy resin (Buehler, Lake Buff, IL, USA). The specimens were sectioned in a bucco-lingual direction with a diamond saw through the center of the restorations under a water coolant. The surfaces were cleaned with phosphoric acid to remove the smear layer. All restorations were polished with 600 grit abrasive paper. For replication purposes, impressions of the polished surfaces were taken immediately after polishing. Vinyl Polysiloxane Impression Material (Imprint II Garant, 3M ESPE St. Paul, MN, USA, Lot 20030424) was used to prepare replicas.

Scanning electron microscopy (SEM) evaluation was performed both on replicas and the specimens. Images of the gold sputter-coated replicas were obtained with a SEM (JSM-840 A; JEOL Ltd., Tokyo, Japan).

The cavity walls were divided into six sections, and each section was 1 mm long (y1, y2, y3, y4, y5, y6) (Figure 1).

The number of gaps at the restoration-dentin interface was analyzed on each section at a 500x magnification in steps of 200 µm. Similar to the

Irie et al.[15] study the number of gaps in each sample was totaled and expressed as the sum of the sample (Figure 2).

Results of the SEM analysis were subjected to non-parametric statistical test procedures. The Kruskal-Wallis test ($p<0.05$) was used for comparison of groups I-V. The Mann-Whitney U test ($p<0.05$) was use for comparison of the pair of teeth in each group.

Results

Results of the quantitative SEM-analysis are presented in Figures 3 through 5. SEM analysis of the restoration-dentin interface revealed widely varying levels of interfacial gap formation for each of the five different groups.

Tables 3 and 4 summarize statistical results of the five different experimental groups for the gap formation in the cavity preparations. Statistical results of the SEM analysis showed fewer gaps in restorations fabricated with self-etching dentin bonding agents than with etch-rinse agents at the restoration-dentin interface in both primary and permanent teeth.

In primary and permanent teeth significant differences were detected between Adper Prompt L-Pop (Figure 3), Prime & Bond NT (Figure 4 C, D), Admira Bond (Figure 4 A, B), and I-Bond (Figure 5 A, B) groups ($p<0,05$). There was not a significant difference between the Prime & Bond NT group and the Gluma One Bond group (Figure 5 C, D) ($p>0,05$). However, the Prime & Bond NT group showed more gaps than the other groups.

When different dentin bonding agent systems were compared, there were more gaps on the y2, y3, y4, and y5 cavity walls in both primary and permanent teeth. Consequently, there were more

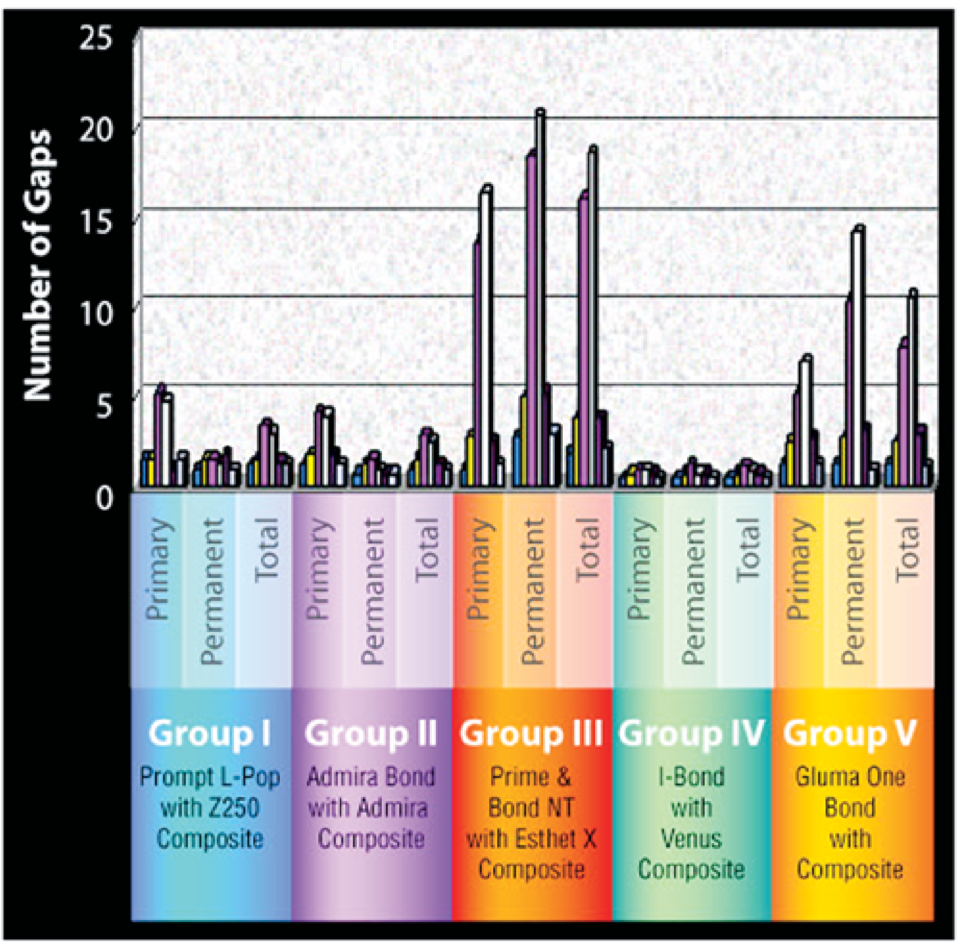


Figure 2. The total number of gaps on different cavity walls.

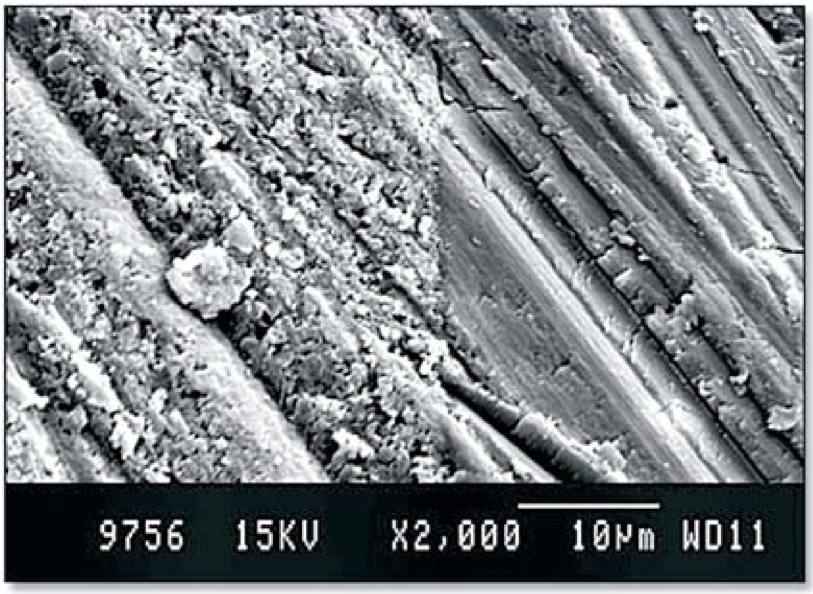


Figure 3. SEM image (x2000) illustrating a section of a primary tooth specimen of Adper Prompt L-Pop (Group I).

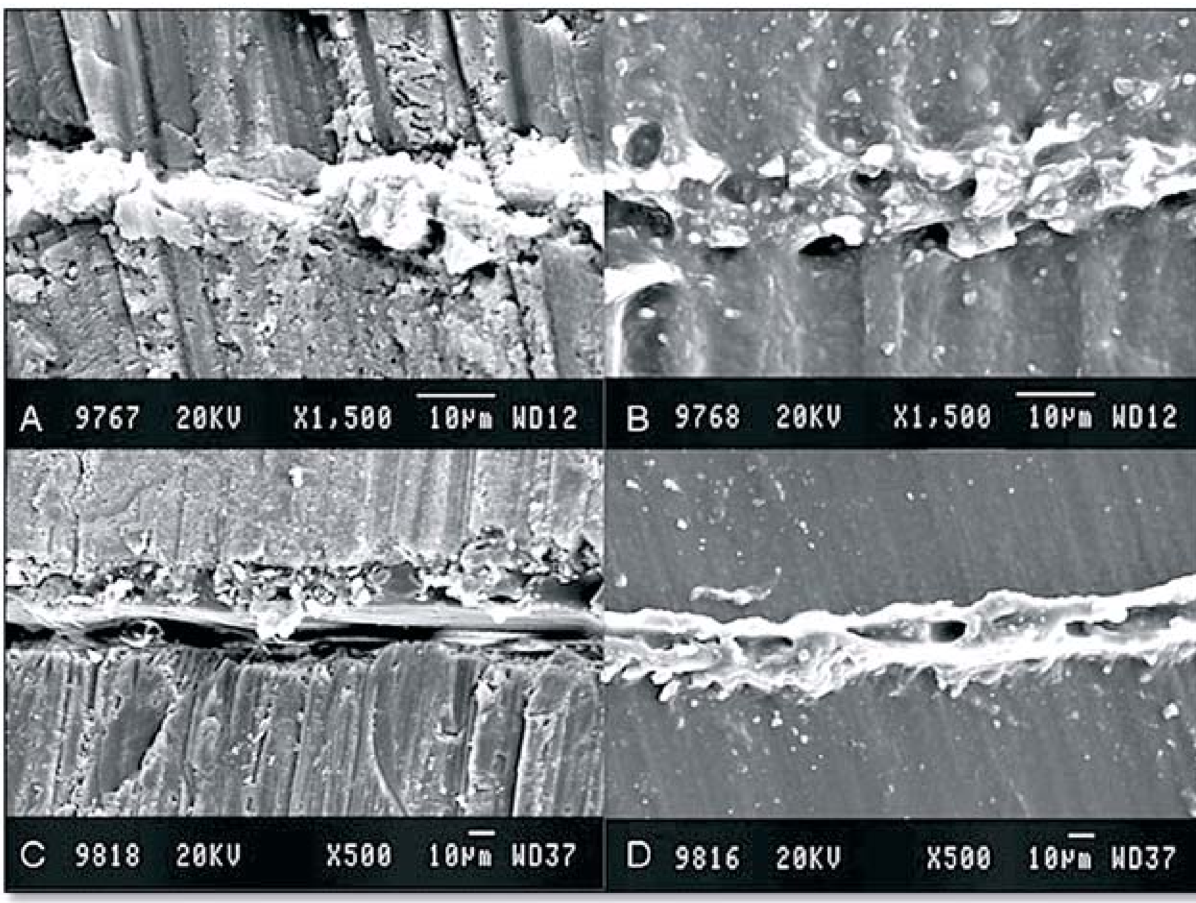


Figure 4. A. SEM image (x1500) illustrating a section of a permanent tooth specimen of Admira Bond (Group II). **B.** SEM image (x1500) of the replica of Admira Bond. **C.** SEM image (x500) illustrating a section of a permanent tooth specimen of Prime & Bond NT (Group III). **D.** SEM image (x500) of the replica of Prime & Bond NT.

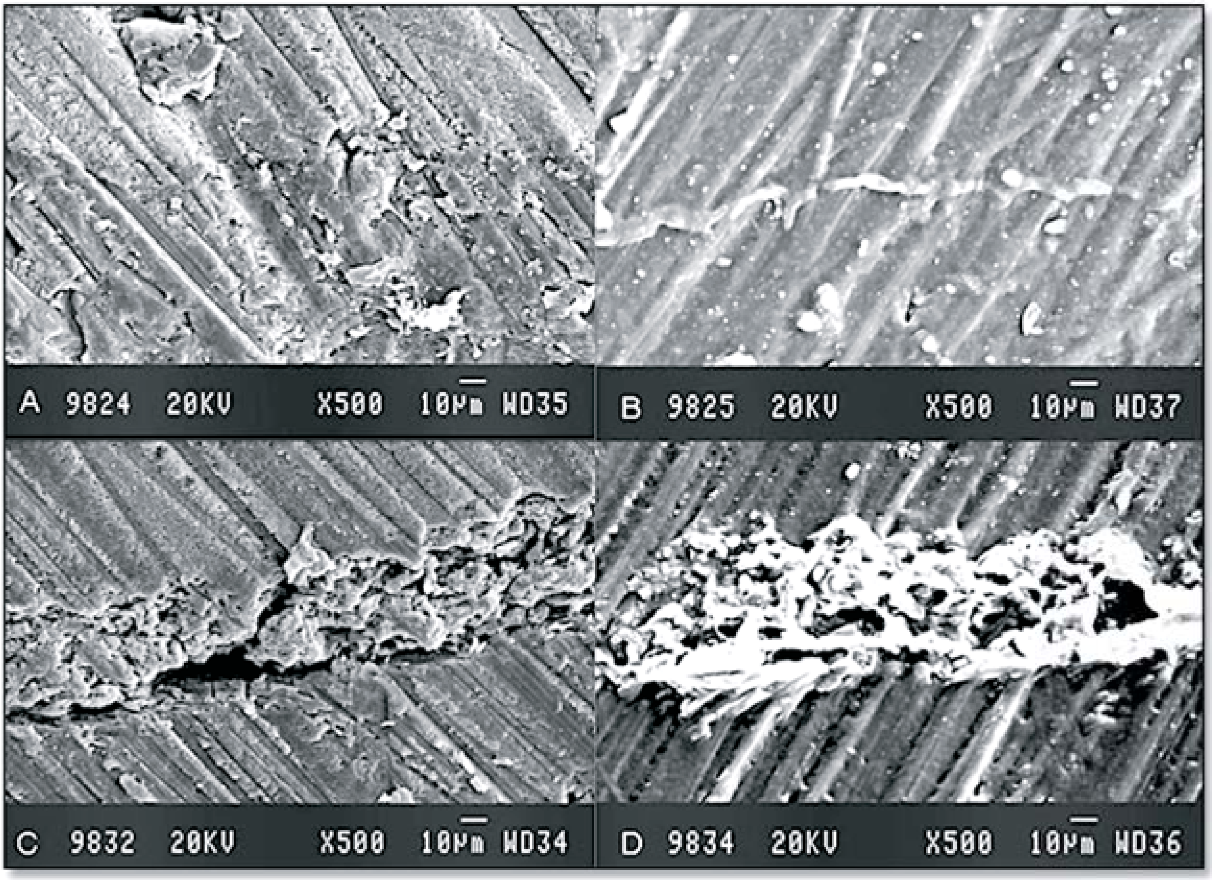


Figure 5. A. SEM image (x500) illustrating a section of a primary tooth specimen of I Bond (Group IV). **B.** SEM image (x500) of the replica of I Bond. **C.** SEM image (x500) illustrating a section of a primary tooth specimen of Gluma One Bond (Group V). **D.** SEM image (x500) of the replica of Gluma One Bond.

Table 3. Results of the statistical analysis; pair-wise comparison of gap formation in Groups I, II, III, IV and V- primary teeth.

Groups	I	II	III	IV
V	n.s.	n.s.	n.s.	n.s.
IV	n.s.	n.s.	Sign.	
III	Sign.	Sign.		
II	n.s.			

(**n.s.**= non-significant $p>0.05$, sign.=significant difference, $p<0.05$)

Table 4. Results of the statistical analysis; pair-wise comparison of gap formation in Groups I, II, III, IV and V- permanent teeth.

Groups	I	II	III	IV
V	n.s.	n.s.	n.s.	n.s.
IV	n.s.	n.s.	Sign.	
III	Sign.	Sign.		
II	n.s.			

(**n.s.**= non-significant $p>0.05$, sign.=significant difference, $p<0.05$)

gaps on the corners and floor of the cavity, but no significant difference was detected between the cavity walls (p>0,05).

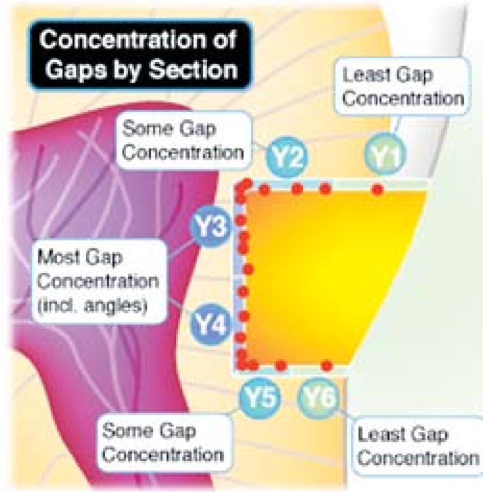
When primary and permanent teeth were compared, no significant difference was detected in the same material group (p>0,05).

Discussion

Factors that influence stress formation include: volumetric polymerization shrinkage; elastic modulus and flow of the resin composite; adherence of the resin composite to the cavity walls; and the configuration factor of the restoration (the ratio of bonded to unbonded composite surfaces).[6,15] The resulting stress inside a composite restoration is dependent on the ratio of bonded and non-bonded surfaces or the C-factor.[6] In the present study, similar to the Hanning and Friedrichs study[6], a cavity design was chosen that strongly limited the flow of the composite resin materials since only one surface of the restorative material was unbonded.

Current restorative techniques rely on bonding to mineralized structures of primary and permanent teeth. It is known both dentitions have similar composition; however, some differences regarding morphology and mineral content have been well documented in the literature.[16] According to Johnsen[13], the primary teeth are less mineralized than permanent teeth. The primary enamel and dentin are also thinner in comparison with the permanent teeth.[17] The morphological structure of the intact primary enamel surface is different from that of the underlying middle enamel layer.[18] Despite the differences between primary and permanent teeth, no significant difference (p<0.05) in gap formation between these groups was found in this study.

In an *in vitro* study by Peutzfeldt et al.[19] polymerization shrinkage and flow of the resin composites were found to be significant determinants of gap formation in resin composite restorations in butt-joint, all-dentin cavities when an adhesive system was used in conjunction with a broad spectrum of resin composites. Layering resin composite has been shown to reduce stresses generated on cavity walls, therefore, the composite resin was inserted using the incremental technique in this study.[20]



To decrease polymerization contraction and to enhance mechanical properties, some manufacturers include nanofillers in the composition. Studies have shown that such fillers can occupy the microscopic spaces in the hybrid layer and also penetrate into the tubuli and participate in tag formation.[21] Prime & Bond NT includes nanofillers, however, in this study there was more gap formation in the Prime & Bond NT group than in the other groups.

Dentin bonding is directly connected to the state of the collagen fibers in that the adhesive must be able to preserve the integrity of these fibers. Good resin diffusion through the collagen matrix is important as is adequate polymerization of the infiltrated resin if the best possible anchoring between resin and dentin is to be achieved. The collagen fibril matrix from which mineral support has been removed must keep its spongy character to enable monomer diffusion. If the dentin dries after the etching agent has been rinsed, the collagen matrix may collapse and, thereby, hinder resin penetration.[22] Minimal gap formations in the restorations made with Adper Prompt L-Pop and I Bond groups in the current study can be due to these factors.

In contrast, breaks between the hybrid layer and tags were often observed in specimens prepared with a water-based system. Since the adhesive contained water it may not have polymerized completely and, thus, may have fractured during specimen preparation.[21] Even though several laboratory studies indicate the choice of acetone-or-water-based systems will influence technique sensitivity, no direct effect of solvent was found in this study. Because of the high vapor pressure of acetone, the risk of interference with polymerization from residues of solvent seems unlikely. However, acetone-based systems depend on a moist dentin surface for optimal infiltration.[23,24]

For water-based systems, the situation is somewhat different. They are less dependent on variations in moistness of the surface, but the solvent is more difficult to vaporize, thus, increasing the risk of incomplete polymerization of the resin.[24] In this study, the bonding agents used in groups which teeth were conditioned with phosphoric acid and then bonded were acetone-based. There was no statistical difference between the Adper Prompt L-Pop group in which a water based bonding agent was used and the I Bond group in which acetone-based bonding agent was used.

To overcome some of the problems associated with dentin bonding, simplified self-etching, all-in-one bonding systems have been developed. The category of bonding agents contains acidic monomers capable of demineralizing the surface.[25] From the above, it is obvious dentin bonding is strongly influenced by the clinician's operating technique. Self-etching adhesives would reduce operator variability when compared with the traditional products that use separate dentin etching.[24] The results of this study support this since the lower technique sensitivity of a self-etching system can be related to a better-standardized conditioning procedure with no need for water rinse or dentin moisture retention.

Compared with other cavity walls, the results of this study showed contraction gaps of resin restoratives were found in the cavity floor and the line angles of the cavity floor (y2, y3, y4, y5). There is more gap formation particularly on the y3 and y4 cavity walls. Light was irradiated from the surface of the filled resin composite during light curing. Because polymerization shrinkage was concentrated in the cavity floor of the specimen, the contraction gaps of resin restoratives were found there.[26] In spite of these findings no statistical difference was found between different cavity walls.

Conclusion

Self-etching bonding systems were determined to be preferable in primary and permanent teeth as a result of the findings of this study. However, further studies should be conducted to determine how to avoid gaps at the line angles and point angles of the cavity preparations and how to maintain a gap free adaptation between resin composite and tooth structure.

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