No Adverse Effect to Bonding Following Caries Disinfection With Chlorhexidine

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ABSTRACT

Purpose: The purpose of this study was to evaluate the effect of 2% chlorhexidine-based cavity disinfectant on the microtensile bond strength of 3 restorative materials to caries-affected and sound primary dentin.
Methods: Eighteen exfoliated primary molars with occlusal caries and 18 sound primary molars were randomly divided into 3 experimental groups, according to the following restorative materials: (1) high-viscosity glass-ionomer cement (GIC; KetacMolar); (2) resin-modified GIC (Vitremer); and (3) dentin adhesive (Prime&Bond NT) with a packable composite (Surefil). The molars were further divided into 2 subgroups according to the application of chlorhexidine-based cavity disinfectant (Consepsis). Standard restoration blocks of 5 mm high were built up over the treated surfaces. Bond strength results were evaluated using by 1-way analysis of variance, and multiple comparisons were done via Tukey's test ($P<.05$).
Results: No statistically significant differences were found between the high-viscosity and resin-modified GIC and composite showed the highest bond strength values on both dentin surfaces. The distribution of failure modes between the high-viscosity and resin-modified GICs were mostly cohesive where adhesive failures were noted significantly in the composite.
Conclusion: Using 2% chlorhexidine gluconate did not interfere with the microtensile bond strength of glass ionomer cements and composite.
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The philosophy of tooth preparation and conservation has greatly changed in the last decade with the introduction of both minimal intervention techniques and tooth-colored restorative materials. Recently, high-viscosity glass ionomer cement (**GIC**) was introduced on market as a restorative material with improved handling and physical properties compared to conventional GIC and has been found successful for restoration of primary teeth.[1]

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The other alternative restorative material in pediatric dentistry is resin-modified GIC (**RMGIC**). This has mechanical properties more improved than conventional GIC and was developed from conventional GIC by adding polymerizable monomers to increase the working time and reduce water sensitivity.[2] Recently, composite resins also gained more importance in the treatment of primary molars.[3,4] Many reports found better physical and clinical properties for composites with a longer survival time than GICs.[5-8] Currently, packable composite resin (**PCR**) has been developed for posterior restorations. PCR is less sticky than previous composites and has a higher viscosity due to modification in filler loading and types.[3]

One of the advantages of tooth-colored restorative materials is the preservation of the sound enamel and dentin with minimal cavitation. Rather than removing sound tooth structure for extension-for-prevention, the noncarious tooth structure is protected by bonded materials (ie, sealant or composite). With the minimal intervention techniques, however, there is more risk of leaving more residual bacteria in the cavity after caries removal, which can result in secondary caries.[9] For this reason, disinfectant solutions have been introduced as alternative means to reduce or eliminate bacteria from cavity preparations that may contribute to secondary caries and restoration failure.[10] It is not known, however, whether such an antibacterial agent may affect the bonding strength of the restorative material to dentin. The results of *in vitro* studies are controversial regarding the disinfectant's effect on adhesion.[10-13] Moreover, there is still not much laboratory data that discusses the bonding of GICs to dentin with the use of cavity disinfectants.

During restoration of carious teeth, clinicians usually deal with sclerotic, caries-infected, or caries-affected dentin. The physical and chemical properties of sound dentin are different from those of caries-affected dentin.[14] Thus, the latter is more porous and softer than sound dentin due to partial demineralization, with a hybrid layer thicker than that of sound dentin.[15-17] Furthermore, the dentin of primary and permanent teeth is different in composition and structure. The concentration of calcium and phosphate in peritubular and intertubular dentin is lower in primary teeth than it is in permanent teeth.[18] In addition, the tubule density of dentin is lower in primary teeth than in permanent teeth.[19,20] Primary teeth have a lesser degree of mineralization and hardness than permanent teeth, which could affect the tested material's bond strength. To date, not much information exists about the influence of disinfectant solutions on bond strength to caries-affected dentin on primary teeth dentin.

The aim of this study was to determine the influence of a chlorhexidine-based cavity disinfectant on the microtensile bond strength (**μTBS**) of high-viscosity and RMGICs and a dentin adhesive with a packable composite to caries-affected and sound dentin in primary teeth and examine the micromorphology of the debonded surfaces under scanning electron microscope (**SEM**).

METHODS

TOOTH SELECTION

Eighteen exfoliated primary mandibular second molars with occlusal carious lesions and 18 sound primary mandibular second molars stored in 0.1% thymol solution for no longer than 1 month after extraction were selected for the study. For the carious teeth, the inclusion criteria were dentinal caries extended no further than the middle one third of the dentin thickness, as verified by radiography. The carious lesion was removed via a slow-speed saw (Isomet, Buehler Ltd, Lake Bluff, Ill) under water lubrication to expose a flat dentin surface. A caries-detector dye (Caries Detector, Kuraray Medical Co, Ltd, Tokyo, Japan) was used to determine that all carious dentin had been removed. The dentin surface was ground until the dentin was no longer stained and finally finished with wet no. 600 grit silicon carbide papers to create a standard smear layer. For the sound teeth, a radiographic examination was made to estimate the level of dentin used for observing the remaining dentin thickness, which was approximately the middle one third of the dentin. The occlusal surfaces of sound teeth were polished with wet no. 600 grit silicon carbide paper.

APPLYING RESTORATIVE MATERIALS

The same clinician carried out the preparation of the restorations to exclude interclinician variations. All the teeth were randomly allocated into 3 groups according to the restorative materials. Each group (N=12: 6 carious and 6 sound teeth) was randomly divided into 2 subgroups of 3 teeth according to the use of disinfection solution. The groups were prepared as follows, and the test materials are presented in Table 1:

In group 1, Ketac Conditioner (3M-ESPE Dental Products, Seefeld, Germany) was applied to the dentin surface for 30 seconds, rinsed for 10 seconds, and air-dried for 5 seconds. In the disinfected group, Consepsis (Ultradent Products, South Jordan, Utah) was applied with its applicator for 60 seconds according to the manufacturer's instructions. Next, Ketac Molar (3M-ESPE Dental Products) powder and liquid were hand-mixed according to manufacturer's instructions. A Teflon matrix (Ultradent Products) was applied, and a 5-mm-high buildup was created on the treated dentin surface. Ketac glaze was then applied and light-cured for 10 seconds with a curing unit LED (Elipar, Trilight, 3M-ESPE Dental Products, St. Paul, Minn). In the nondisinfected group, Ketac Molar was applied according to manufacturer's instructions.

In group 2 (the disinfected group), following the application of Consepsis, Vitremer Primer (3M-ESPE Dental Products) was applied to dentin surfaces for 30 seconds, air-dried for 15 seconds, and light-cured for 20 seconds. Vitremer (3M-ESPE Dental Products) was incrementally inserted with a 5-mm thickness and light-cured for 40 seconds. In the nondisinfected group, Vitremer was applied according to manufacturer's instructions.

In group 3, Etchant (36% ortophosphoric acid, Dentsply De Trey, Konstanz, Germany) was applied to the dentin surface for 15 seconds and rinsed for 15 seconds. In the disinfected group, following the application of Consepsis, one layer of bonding agent (Prime&Bond NT, Dentsply De Trey) was applied for 20 seconds, air-dried for 5 seconds, and light-cured for 20 seconds. Then, Surefil (Dentsply De Trey) was placed incrementally. The resin buildup's thickness was 5 mm, and each increment was light-cured for 40 seconds using the same curing unit used in the other groups. In the nondisinfected group, dentin adhesive and Surefil were applied according to the manufacturer's instructions.

MICROTENSILE BOND STRENGTH TEST

After the restorations were completed, the teeth were stored in distilled water at 37°C for 24 hours prior to preparation for the bond test. Next, the roots were removed 2 mm below the cementoenamel junction with a slow-speed diamond saw under water spray. Each tooth was cut into a series of approximately 1-mm matchsticks (Figure 1). Each slice was cut by means of a water-cooled diamond blade (Isomet, Buehler Ltd, Lake Bluff, Ill), with approximately 10 to 15 sticks prepared. The specimens were then mounted in a specially designed testing grip attached with cyanoacrylate glue (Zapit, Dental Ventures of America, Corona, Calif) to the Bencor Multi-T (Danville Engineering Co, Danville, Calif) and stressed in tension at a crosshead-speed of 0.5 mm/minute using a universal testing machine (model no. 5544, Instron Corp, Canton, Mass). The tensile force at failure was recorded, and the results were transformed to tensile strength

After testing, the fracture modes of each specimen were determined by means of a light microscope (LG-PS2, Olympus Co, Tokyo, Japan) at X10 magnification and the mode of failure for each specimen was then classified into 1 of 4 types, as follows:

1. type 1—adhesive failure between cement and dentin;
2. type 2—mixed failure and partially adhesive failure between dentin and cement and partially cohesive failure in cement;
3. type 3—cohesive failure in dentin; and
4. type 4—cohesive failure in cement.

Table 1. Materials used in the study

Product (Manufacturer)	Batch number	Components	Ingredients
Surefil (Dentsply/Caulk Milford, DE, USA)	010320	**Packable resin-based composite**	Bis-GMA, TEGDMA, bis-EMA, barium floroaluminoborosilicate glass fumed silica, stabilizers, photoinitiators
Prime & Bond NT (Dentsply De Trey, Konstanz, Germany)	030822	**Conditioner**	36% Phosphoric acid gel
		Bond	PENTA, UDMA, Resin R5-62-1, T-resin, D-resin, Nanofiller, Initiators, Stabilizer, Cetylaminehydrofluoride, Acetone
Ketac Molar (3 M ESPE, Seefeld, Germany)	01128273	**Powder**	calcium aluminiumlanthanum-fluorosilicate glass Acrylic acid-maleic acid copolymer pigments
		Liquid	water Acrylic acid-maleic acid copolymer Tartaric acid
		Ketac Conditioner	25% polyacryclic acid
Vitremer (3M Dental Products, St. Paul, MN, USA)	3303MP-A3	**Primer**	Primer: 46% HEMA, 39% ethyl alcohol, 15% Vitrebond copolymer
		Powder	Fluori-aluminosilicate glass, potassium persulfate, ascorbic acid
		Liquid	50% Polyacrylic acid copolymer, 20% HEMA, water, 13% carboxylic acid copolymer
Consepsis (Ultradent, South Jordan, UT, USA)	80100	**Chlorhexidine Gluconate antibacterial solution**	2% chlorhexidine gluconate

The most representative fractured specimens were observed under SEM (JSM-5500; Jeol Ltd, Tokyo, Japan).

Statistical analysis was accomplished using SPSS 10.0 software (SPSS Inc, Chicago, Ill). For each group, bond strength data was analyzed using a 1-way analysis of variance to detect any statistical differences and multiple comparisons were done via Tukey's test. Fracture modes were analyzed using the Mann-Whitney U and Kruskall-Wallis tests.

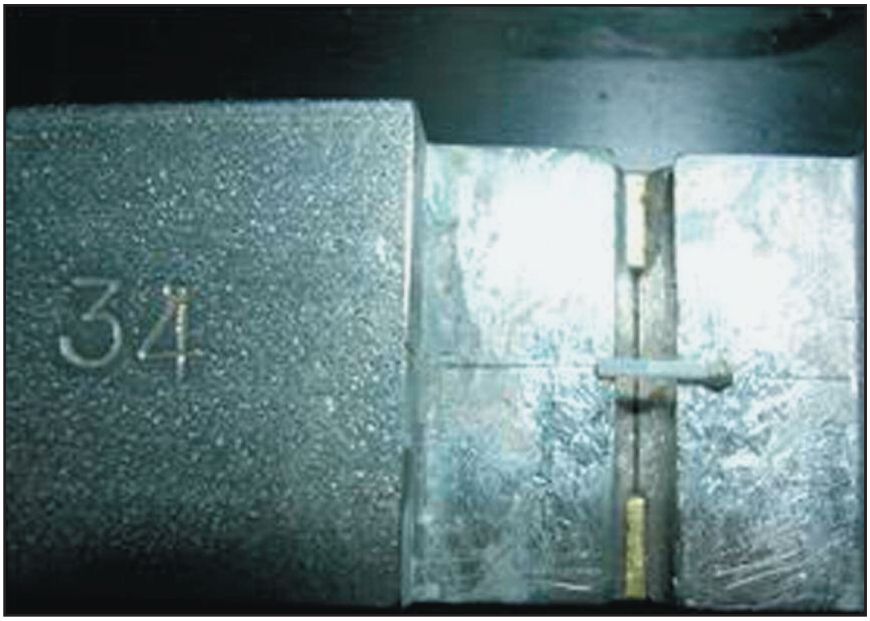

Figure 1. Photograph of a matchstick

RESULTS

The mean μTBS (±SD) of the materials are shown in Table 2. High-viscosity and RMGICs showed similar μTBS (P=.065). The groups restored with packable composite showed statistically higher μTBS to both caries-affected and sound dentin when compared to GICs. The usage of chlorhexidine-based cavity disinfectant had no significant influence on the material's μTBS values to in both caries-affected and sound dentin.

The composite group showed mostly type 1 failure, whereas the main failure modes were mostly type 4 in the RMGIC and high-viscosity GIC groups (Table 3). There were no cohesive failures in dentin in any of the specimens. The distribution of failure modes of composite differed significantly from the other restorative materials.

SEM images of the debonded tooth surfaces of different restorative materials are shown in Figures 2, 3, and 4. In a specimen with cohesive failure of high-viscosity GIC, the dentinal surface was fully covered with the restorative material (Figure 2a-b). In the RMGIC group, some material was adhered to the dentin surface and the dentin was partly denuded (Figure 3 a-b). Surfaces with adhesive failures in the composite group showed no adherent material, and dentinal tubules were exposed (Figure 4 a-b).

Table 2. μTBS of the restorative materials with and without the application of the disinfectant

Groups and materials	Mean μTBS ±SD (Mpa) Sound dentin	Mean μTBS ±SD (Mpa) Caries-Affected Dentin
KetacMolar		
With disinfectant	8.7±4.3 *	7.1±5.2 *
Without disinfectant	9.2±5.2 *	10.3±6.6 *
Vitremer		
With disinfectant	12.4±5.7 *	11.2±4.8 *
Without disinfectant	14.4±6.6 *	13.8±4.9 *
Surefil		
With disinfectant	22.6±6.9 §	20.2±5.8 §
Without disinfectant	23.2±6.2 §	22.1±6.2 §

Statistically similar groups are labeled with the same symbol and different symbol (,§) shows a significantly different group (P<0.05)*

DISCUSSION

In the present study, the influence of a chlorhexidine-based cavity disinfectant on the μTBS of 3 different tooth-colored restorative materials on sound and caries-affected primary dentin was investigated. The reason for pretreatment of dentin with chlorhexidine after etching and prior to placing restorative materials was to eliminate residual bacteria which remain after the cavity preparation. Chlorhexidine was preferred because it continues to kill bacteria for several hours by binding to the amino acids in the dentin,[21] making it a good antimicrobial agent.[13,22] There is not much information, however, about how this agent may affect the bonding of glass ionomer materials.

Tulunoglu et al[12] found that chlorhexidine-containing cavity disinfectant increased microleakage scores when used prior to the implementation of Syntac and Prime&Bond dentin adhesive systems. They reported that there might have been some negative interaction between the cavity disinfectants and dentin bonding agents. Vieira et al[23] also investigated the effect on bond strength of chlorhexidine as a cavity disinfectant on primary tooth dentin. It was found that 2% chlorhexidine had an adverse effect on the adhesive system (Single Bond) when used prior to etching. The sequence for disinfectant application was different in the present study. The disinfectant was applied after etching,

Table 3. Failure modes between materials and primary teeth dentin

Groups and materials			Types of failure Type I (%)	Type II (%)	Type III (%)	Type IV (%)
Ketac Molar	caries affected dentin	with disinfectant	7	19	-	74
		without disinfectant*	-	23	-	77
	sound dentin	with disinfectant*	3	16	-	81
		without disinfectant*	-	22	-	88
Vitremer	caries affected dentin	with disinfectant*	28	20	-	52
		without disinfectant*	9	28	-	63
	sound dentin	with disinfectant*	12	21	-	67
		without disinfectant*	5	23	-	72
Surefil with Prime&Bond NT	caries affected dentin	with disinfectant §	76	24	-	-
		without disinfectant §	88	12		-
	sound dentin	with disinfectant §	92	8	-	-
		without disinfectant §	98	2	-	-

Statistically similar groups are labeled with the same symbol and different symbol (§) shows a significantly different group (P<0.05)

and this application agreed with a study by Perdigaõ et al.[24] They observed that the use of chlorhexidine as a cavity disinfectant after conditioning of the dentin did not decrease the adhesion of the All-Bond 2 adhesive system. Furthermore, there are also some studies which showed that applying chlorhexidine after an acid-etching procedure had increased bond strength.[11,25] Pappas et al[25] treated the permanent dentin with 3-step disinfection (chlorhexidine, Tubulicid, sodium hypochlorite) before dentin bonding and found that 3-step disinfection improved the bond strength values when compared to conventional bonding techniques. Cunningham et al[11] also showed that a 2% chlorhexidine cavity wash can be used without negatively affecting the shear bond strength of RMGICs, Vitremer, Fuji II LC, and Photac-Fil.

Several studies have investigated the bond strength of composites on the dentin of primary teeth using several adhesive systems, reporting values ranging from 6.2 to 22.32 MPa.[26-28] These values are consistent with the present study's findings (23.2 Mpa on sound dentin and 22.1 Mpa on caries-affected dentin) for tested composite (Surefil) on sound and caries-affected dentin, with no significant difference between the µTSB values. These results agree with Nakornchi et al[29] and Way et al.[30] Cehreli et al,[31] who evaluated the bond strengths of 3 polyacid-modified resin composites and one RMGIC, however, found that µTBS values were statistically higher on sound primary dentin compared to caries-simulated primary dentin.

In the present study, there were no significant differences in the distribution of failure modes between the high-viscosity GIC and RMGIC, where adhesive failures were noted significantly in the composite. The cohesive mode of failure in the cement itself is reported to be a typical finding for GIC,[11] which was also observed in most of the specimens of the high-viscosity GIC used in the present study. This failure mode has often been interpreted as showing that the bond to the dentin was stronger than the cement's cohesive strength. In addition, it is suggested that GIC always contains numerous air inclusions that can act as stress points, thus giving rise to the increased likelihood of cohesive failure within the cement.[28]

This same phenomenon can also occur in resin-based systems, but the number of defects within the resin is much less than in GIC. This may be one of the reasons to explain different modes of failure between GICs and composites. The mechanisms of bonding for the RMGIC and composites are quite different from GIC. In a study of Burrow et al,[28] it was found that the bond strengths for the RMGIC and resin composite were similar. They explained the similarity in the results of RMGIC and composite

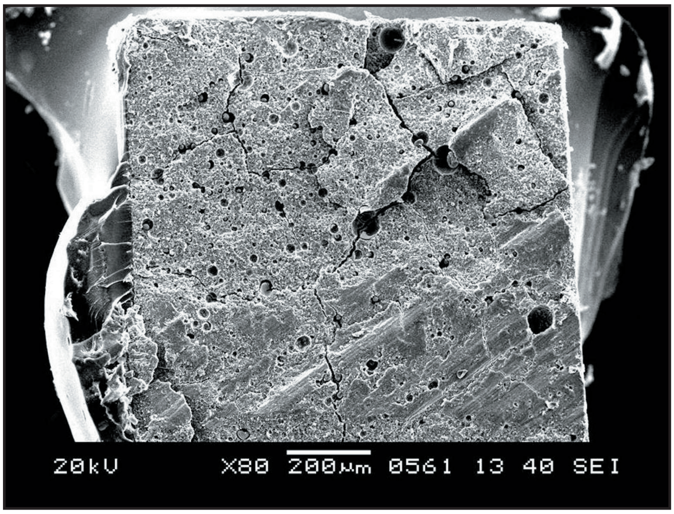

Figure 2a. Sound primary tooth dentin restored with Ketac Molar after the application of Consepsis showed cohesive fracture.

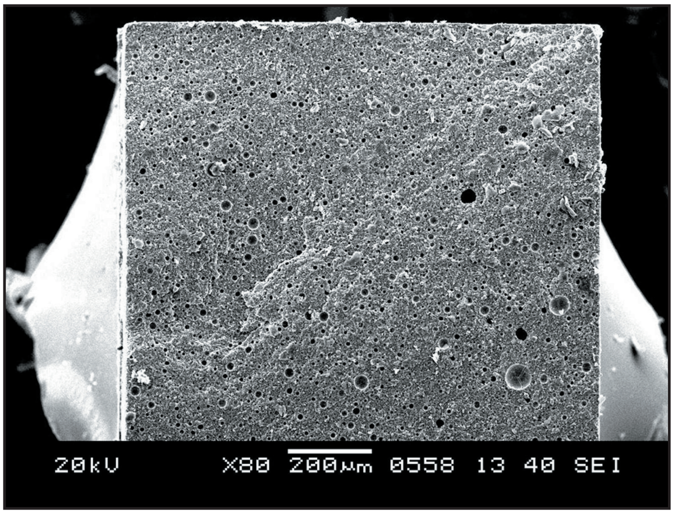

Figure 2b. Caries affected primary tooth dentin restored with Ketac Molar without the application of Consepsis showed cohesive fracture.

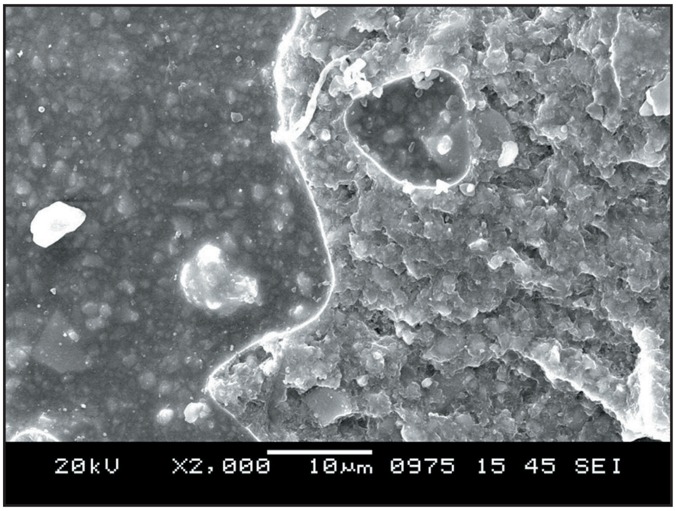

Figure 3a. Representative SEM image of cohesive failure pattern observed for Vitremer after the application of Consepsis in the caries affected primary tooth dentin.

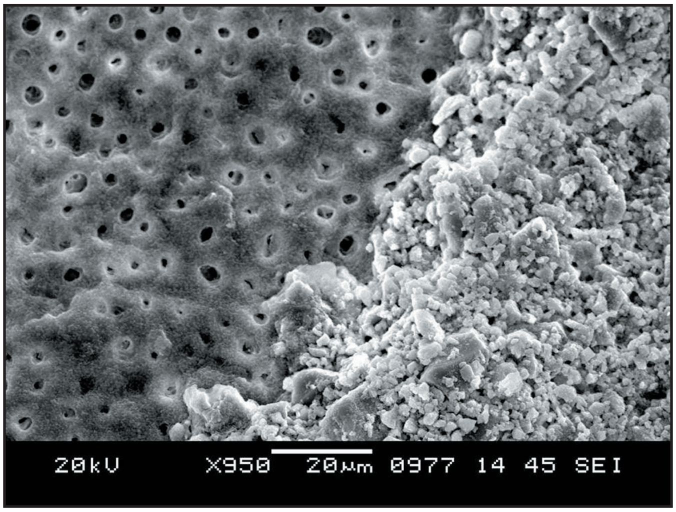

Figure 3b. Adhesive fracture on the left half and cohesive resin fracture on the right hand in the caries affected primary tooth dentin restored with Vitremer without the application of Consepsis.

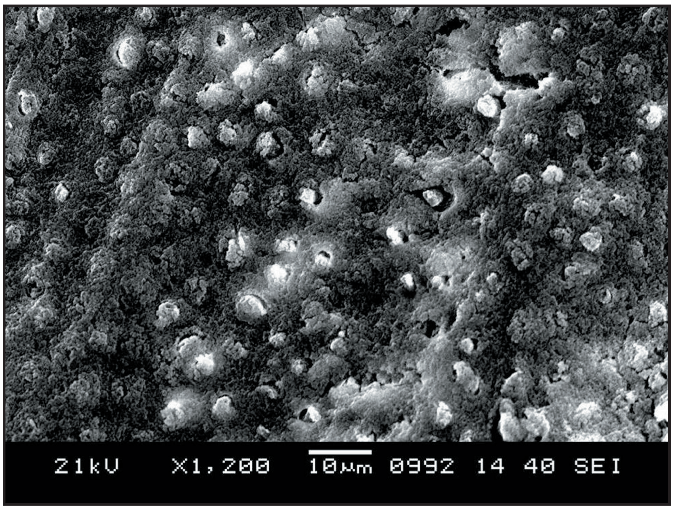

Figure 4a. This SEM photograph showed adhesive failure with Surefil after the application of Consepsis in sound primary teeth dentin.

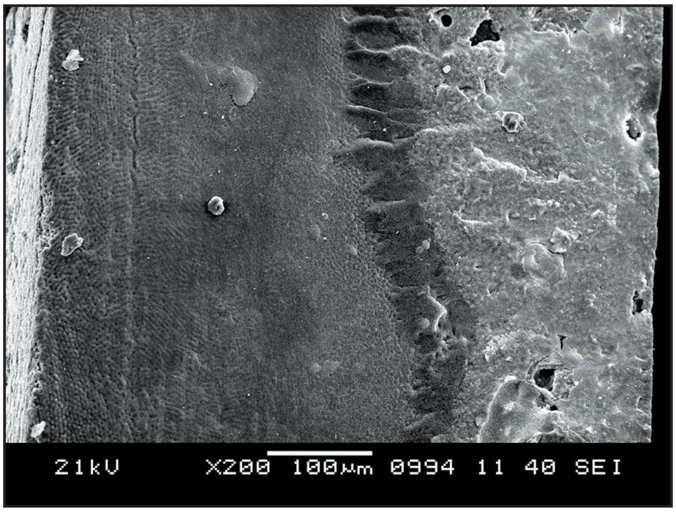

Figure 4b. A debonded specimen in which adhesive fracture occurred predominantly within Prime&Bond NT and at the bottom of Surefil in the sound primary teeth without the application of Consepsis.

relating to the formation of a hybrid layer. Similar findings have been also observed for RMGIC in another study.[32] In the present study, Vitremer was used as a RMGIC different from a RMGIC (Fuji II LC) tested by Burrow et al[28] and Tanumiharja et al.[32] The variation in the bond strengths of RMGICs could also relate more to their individual material compositions rather than their bonding mechanisms. Furthermore, Vitremer was applied after the primer, but no etching was used according to the manufacturer's recommendations. In the aforementioned studies,[28,32] however, a conditioner was administered before applying RMGIC, resulting in a hybrid-like layer. This could be why different results were found.

CONCLUSIONS

The use of chlorhexidine-gluconate-based cavity disinfectant did not significantly influence the bonding ability of glass ionomer cements or resin to penetrate on primary caries-affected and sound dentin. This suggests that the chlorhexidine-gluconate-based cavity disinfectant might be used as an antibacterial agent to reduce the potential for residual caries and postoperative sensitivity in clinical conditions.

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