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RESEARCH ARTICLE

Bond Strength to Primary Teeth Dentin Following Disinfection with 2% Chlorhexidine

Faika Y Abdelmegid*

Department of Oral Medicine and Diagnostic Sciences, College of Dentistry, King Saud University, Kingdom of Saudi Arabia

***Corresponding author:** *Associate Prof. Faika Y Abdelmegid, BDS, MS, Department of Oral Medicine and Diagnostic Sciences, College of Dentistry, King Saud University, PO BOX: 60169, Riyadh, Kingdom of Saudi Arabia, E-mail: famegid@hotmail.com; fabdelmegid@ksu.edu.sa*

Abstract

Objectives: To assess the influence of 2% chlorhexidine gluconate applied for 20 or 40 seconds on the Shear Bond Strength (SBS) of a nanohybrid resin-composite Filtek Z350XT with Single Bond Universal Adhesive and Photac Fil resin-modified glass-ionomer with Ketac conditioner to Caries Affected Dentin (CAD) of primary teeth.

Methods: Seventy-two specimens of CAD primary dentin were randomly divided into 6 groups, 12 each according to the materials and application of 2% chlorhexidine (no application or application for 20 or 40 seconds). Restorative materials were applied using a standard PVC tube. SBS was measured using an Instron machine running at a crosshead speed of 0.5 mm/min. The modes of failures/fractures were verified using stereomicroscope.

Results: Mean (± SD) SBS in MPa of Filtek Z350XT and Photac Fil with no application of chlorhexidine or after application of chlorhexidine for 20 or 40 seconds were 14.13 ± 2.09, 16.45 ± 2.41, and 15.91 ± 3.11, 12.56 ± 2.44, 14.10 ± 3.10 and 13.83 ± 3.11, respectively. Regardless of the surface treatment, Filtek Z350XT showed significantly greater SBS than Photac Fil ($p = 0.01$). The effect of surface treatment on SBS was not statistically significantly different ($p = 0.06$) from one another for each tested material. Stereoscopic examination of the debonded samples of all groups of Filtek Z350XT exhibited mostly cohesive fracture of the material while for Photac Fil exhibited mostly adhesive fracture. Failure mode analysis revealed significant differences ($p < 0.0001$) between Filtek Z350XT and Photac Fil.

Conclusions: The nanohybrid resin-composite Filtek Z350XT with Single Bond Universal Adhesive demonstrated higher shear bond strength than Photac Fil resin-modified glass-ionomer with Ketac conditioner to CAD dentin of primary teeth. The 2% chlorhexidine gluconate applied for 20 or 40 seconds before acid etching or conditioning of the CAD dentin did not affect SBS of the two materials. The mode of failure of Filtek Z350XT exhibited mostly cohesive fracture of the material while for Photac Fil exhibited mostly adhesive fracture.

Keywords

Chlorhexidine gluconate, Primary teeth, Shear bond strength, Dentin disinfection

Introduction

In clinical practice, the most frequent tooth substrate that dentists restore is demineralized dentin or Caries-Affected Dentin (CAD) [1]. Therefore, it is important to understand the CAD's physical properties and mechanism of adhesion for the advancement of conservative restorative dentistry. Exploration of interfaces between the adhesive in sound and carious dentin may increase our appreciation on how bonding to dentin is affected by the properties of dentin in primary teeth. The bond of sound dentin to the adhesive is stronger than with CAD [2] and hence, the reduced bond strength leads to failure of the restoration over time. This problem remains unresolved and has raised interest in studies of the strength of the bond between the sound or CAD and restorative materials.

Carious dentin consists of two layers, the inner less infected, demineralized with possible repairing layer and the outer necrotic, highly infected layer [3]. Clinically, after removing caries where the restorative material is bonded, CAD is frequently encountered [4]. Clinically, dentists are frequently working with caries infected dentin, sclerotic, CAD [4]. The chemical and physical characteristics of CAD are different from those of sound dentin [5]. Partial demineralization of CAD makes it soft-

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Table 1: Descriptive statistics of the SBS in MPa to dentin of primary molars (n = 12).

Group #	Material	Adhesive	Surface Treatment	Mean	Std Dev	Minimum	Maximum
1	Filtek Z350XT	Single Bond total-etch	No treatment (Control)	14.13	2.09	7.63	13.94
2	Filtek Z350XT	Single Bond total-etch	chlorhexidine for 20 seconds	16.45	2.41	9.35	17.47
3	Filtek Z350XT	Single Bond total-etch	chlorhexidine for 40 seconds	15.91	3.11	9.48	18.48
4	Photac Fil	Ketac™ conditioner	No treatment (Control)	12.56	2.44	6.24	12.91
5	Photac Fil	Ketac™ conditioner	chlorhexidine for 20 seconds	14.10	3.10	5.93	14.97
6	Photac Fil	Ketac™ conditioner	chlorhexidine for 40 seconds	13.83	3.11	5.97	15.47

er and more porous than sound dentin, with a thick hybrid layer compared to sound dentin [6,7]. Bonding to CAD and sound dentin depend on the adhesive systems used and the type of dentin [8].

With minimal intervention techniques, however, there is greater 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 decrease or eradicate bacteria during preparations of cavities that may contribute to secondary caries and restoration failure [10]. Chlorhexidine is commonly used broad-spectrum antiseptic or antibacterial materials in dentistry. It has demonstrated to be very effective in the maintenance of plaque control and gingivitis in both short- and long-term *in vivo* studies without developing resistant organisms [11,12]. Chlorhexidine solutions have been also suggested to be placed after cavity preparation to disinfect dentin [10]. A study evaluated the effect of using 2% chlorhexidine to primary dentin for 30 seconds following application of phosphoric acid concluded that its application at low concentrations increase bond strength over time and prevent hybrid layer degradation [13]. The results of *in vitro* investigations are debatable regarding the disinfectant's effect on adhesion [10,14,15]. Because of the conflicting results reported in the above studies regarding bonding to CAD and minimal information about bonding the new restorative materials to CAD of primary teeth after using disinfectant solutions. Hence, the purposes of this *in vitro* study were to determine the SBS of a nanohybrid resin-composite Filtek Z350XT with Single Bond Universal Adhesive and Photac Fil resin-modified glass-ionomer with Ketac conditioner to CAD of primary teeth after using chlorhexidine as cavity disinfectant for 20 or 40 seconds and determine failure mode of fractured surfaces using stereomicroscope. The null hypothesis was there is no difference in the effect of the application of chlorhexidine cavity disinfectant for 20 or 40 seconds on the SBS of the two tested restorative materials to CAD of primary teeth.

Materials and Methods

Preparation of specimens

Seventy-two extracted primary molars with mild to moderate caries were stored in 0.1% thymol to use in this investigation. Caries removal with round carbide burs (SS WHITE, New Jersey, USA) in a slow-speed handpiece was completed leaving CAD using the properties of visual inspection and degree of hardness to a sharp excavator [8]. Teeth were then prepared with the occlusal surfaces exposed and mounted inside a tube-shaped plastic rings, 3 cm × 3 cm using self-polymerizing acrylic resin (Ortho-Jet, Lang Dental MFG.Co., Inc., IL, USA). Then, the occlusal surfaces were polished with 240, 320, 400, and 600 silicon carbide paper (JEANWIRTZ GmbH & Co. Charlottestrabe Dusseldorf W. Germany) under running water to produce a uniform surface and similar smear layer. Specimens were randomly allocated into 6/groups of 12/each (Table 1) and kept for 24 hours in distilled water. Two examiners assessed CAD which was left on the dentin surface. For the inter-examiner reliability in evaluating the type of dentin, Kappa was 0.90, which shows very good agreement.

Bonding procedures

Consepsis (Ultradent Products, Inc. South Jordan, UT, USA), a 2% chlorhexidine gluconate was applied to the experimental groups using a disposable brush tip and left undisturbed for 20 or 40 seconds, rinsed with water for 20 seconds and dried with absorbent paper. A nanohybrid resin-composite Filtek Z350XT with Single Bond Universal Adhesive (3M ESPE St. Paul, MN, USA) and Photac Fil Quick Aplicap resin-modified glass-ionomer with Ketac conditioner (3M ESPE) were used in this investigation. The dentin surface was treated according to the instructions of the manufacturer of each material and light-cured (Elipar S10 LED Curing Light - 3M ESPE) according to the manufacturer's instructions. Restorative materials were applied using a standard PVC tube with a height of 2-mm and internal diameter of 2-mm which was positioned perpendicular to the dentin and each material was carefully inserted into the tube and cured according to the instructions of the manufacturer. All groups were stored for 72 hours in distilled water at room temperature (24 °C) prior to thermocycling for 1,000 cycles between 5° and 55 °C with a 20-sec dwell time and transfer time of 10 s based on the standards of the International Organization for Standardization [16,17].

Table 2: Frequency and percentage of bond failure type.

Group #	Cohesive Fracture of the Material		Adhesive Fracture		Cohesive Fracture of Dentin	
	N	%	N	%	N	%
1	8	66.67	3	25	1	8.33
2	8	66.67	2	16.67	2	16.67
3	9	75	2	16.67	1	8.33
4	4	33.33	7	58.33	1	8.33
5	3	25	8	66.67	1	8.33
6	4	33.33	7	58.33	1	8.33

Bond strength test

SBS was determined using a universal testing machine (Instron, model no. 8500, Canton, MA, USA) at 0.5 mm/minute crosshead speed and expressed in MPa.

Evaluation of failure mode

Two investigators evaluated fractured surfaces under a stereomicroscope (Nikon Model C-DSD230, Nikon Co. Tokyo, Japan) with digital camera (DXM1200F Nikon Co. Tokyo, Japan) at X25 magnification. Failures were classified as adhesive fracture interface (100% of the bonded interface failed between dentin and adhesive bonding), cohesive fracture of the material (100% of failure in the material), and cohesive fracture of dentin (100% of failure in the dentin). For the inter-examiner reliability in evaluating the three types of failures, Kappa was 0.83 showing very good agreement between the two examiners.

Statistical analysis

Descriptive statistics and one-way ANOVA and Tukey HSD test were applied to compare SBS across different groups. A ($p < 0.05$) was used as a level for statistical significance. Cohen's kappa statistics was determined to compute agreement between the two examiners in evaluating dentin and failure types. Software Package Statistical Analysis (SPSS) statistical software version 16 (SPSS Inc., Chicago, IL, USA) was used.

Results

The outcomes of the SBS expressed in MPa and the descriptive statistics are presented in Table 1. Mean (± SD) SBS in MPa of Filtek Z350XT with no application of chlorhexidine or after application of chlorhexidine for 20 or 40 seconds were 14.13 ± 2.09, 16.45 ± 2.41, and 15.91 ± 3.11, respectively. While the mean SBS of Photac Fil with no application of chlorhexidine or after application of chlorhexidine for 20 or 40 seconds were 12.56 ± 2.44, 14.10 ± 3.10 and 13.83 ± 3.11, respectively.

An ANOVA model was used to analyze the data. Factors initially included were type of material, type of surface treatment, and their interaction. The interaction was found to be not significant, so it was removed, leaving a main effect only model. The ANOVA indicated that there was statistically significant difference between the two materials. Regardless of the surface treatment, Filtek Z350XT showed significantly greater SBS than Photac Fil ($p = 0.01$). The effect of surface treatment on SBS was not statistically significantly different ($p = 0.06$) from one another for each tested material.

Table 2 shows the results of the types of fractures observed. Stereoscopic examination of the debonded samples of all groups of Filtek Z350XT exhibited mostly cohesive fracture of the material while for Photac Fil exhibited mostly adhesive fracture. Failure mode analysis revealed significant differences ($p < 0.0001$) between Filtek Z350XT and Photac Fil.

Discussion

The null hypothesis of this study was partially rejected, as there was a difference in the bond strength of the two tested materials after the application of chlorhexidine cavity disinfectant but not the application time to CAD of primary teeth. The nanohybrid resin-composite Filtek Z350XT with Single Bond Universal Adhesive demonstrated higher shear bond strength than Photac Fil light-curing glass-ionomer with Ketac conditioner to CAD of primary teeth. Another investigation indicated no significant difference in bond strength with the self-etch adhesive to CAD compared to sound dentin of primary teeth and significantly higher bond strength when the conventional adhesive was used [18].

Investigation using different adhesives and restorative materials reported bond strength ranging from 6.2 to 18.2 MPa to dentin of primary teeth [19-21]. The reported numbers are similar with the results of this study for both tested restorative materials. Variations in bond strength can reflect many factors including adhesive and bond strength used, the quality and location of dentin, and the specimen storage medium [8,22,23]. Investigation of resin-modified glass-ionomer bonded to carious and sound primary dentin showed greater SBS when pretreated with polyacrylic acid, except for Vitrebond on sound dentin [24]. Lesser bond strengths and adhesive fracture were found for Photac Fil in the present study, indicating that SBS may represent the strength of adhesive bonding by itself. Another factor to consider is the bond strength of adhesives to dentin is the calcium content, which reduced when dentin is closer to the pulp, resulting in lesser bond strengths [19]. In the present study, the dentin was ground to a uniform surface and location. However, despite the effort to have the bonded surface at the same distance from the pulp, that may not be might possible and the

surfaces represent different distances from the pulp. In addition, bond strength in deep dentin has higher moisture content and less intertubular material [22]. Similarly, the bond strength of dentin may be inconsistent due to different organic and water content [24].

Adhesives share main part in stabilizing the hybrid layer as well as creating extension tags into the dentinal tubules [25]. The mechanism of bonding is established on the effect of hybridization and formation of resin tags [26,27]. The ethanol and water in Single Bond may assist in penetration of resin into the collagen structure [28]. Compared to permanent teeth, smear layers are easier to remove from primary, which may suggest greater reactivity to the acidic conditioners used on dentin [29]. A study reported that 2% chlorhexidine reduce SBS of Single Bond to dentin than the etch gel with chlorhexidine and the acid etch alone [30]. A study concluded that after etching the dentin, the use of 2% chlorhexidine and 1% benzalkonium chloride solutions, as cavity disinfectants did not influence the tensile and SBS of One Step and Optibond Solo [31]. Another study indicated significant lower bond strength to sound and CAD of primary teeth compared with permanent teeth [32]. A study concluded that CAD bond strength and nanoleakage in primary teeth are negatively affected after using different adhesive systems [33]. In this investigation, the mode of failure of Filtek Z350XT exhibited mostly cohesive fracture of the material while Photac Fil exhibited mostly adhesive fracture. A previous study reported adhesive failures were more frequently seen in primary dentin [34]. Another study concluded that use of chlorhexidine interferes with the SBS of resin-modified glass-ionomer cement to dentin [35]. Another study using resin-composite reported that cavity disinfectants might be material specific regarding their interactions with different dentin bonding materials [10]. More studies found that chlorhexidine application before and after acid etching did not significantly influenced the dentin bonding system [36-38]. However, another study indicated that application of the chlorhexidine before and after acid etching significantly decreased the SBS to dentin [14]. The outcomes of this *in vitro* investigation showed that the mean SBS was less than 17.6 Mpa, which considered the minimum value recommended for bond strength to dentin in primary and permanent teeth [39]. A recent study showed the association between the concentration of chlorhexidine and the bond strength is not linear [40].

The results of this investigation should consider the limitations including the restricted number of restorative materials used. Diverse and additional materials are beneficial to test. In addition, the study did not test application of chlorhexidine on the SBS immediately, after shorter application time, and for aged specimens. However, even with these limitations, the study indicated encouraging results of the *in vitro* values*, which* may have clinical implications. Another limitation is it is *in vitro* setting and the clinical condition in the mouth is not easy to mimic in the laboratory [41]. However, in this *in vitro* study, standardization of experimental conditions was advantage and the results demonstrated a clear correlation between SBS of the two tested materials to CAD of primary teeth.

Conclusions

Under the experimental conditions of this *in vitro* investigation, the results of this study concluded that:

1. The nanohybrid resin-composite Filtek Z350XT with Single Bond Universal Adhesive demonstrated higher shear bond strength than Photac Fil resin-modified glass-ionomer with Ketac conditioner to CAD of primary teeth.
2. The 2% chlorhexidine gluconate applied for 20 or 40 seconds before acid etching or conditioning of the CAD did not influence shear bond strength of Filtek Z350XT and Photac Fil.
3. The mode of failure of Filtek Z350XT was mostly cohesive fracture of the material while Photac Fil exhibited mostly adhesive fracture.

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