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CVD tip or diamond bur: can they influence the bond strength of a total-etch adhesive to dentin?

Pontas diamantadas e CVD: podem influenciar na força de união de um adesivo convencional à dentina?

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ABSTRACT

Objective: Evaluate the microtensile bond strength of a total-etch adhesive to dentin, using a CVD tip or diamond bur for dentin preparation and varying the etching time. **Material and Methods:** The dentin from the buccal surface of sixty bovine teeth was exposed and prepared using two different methods (n = 30): Group 1 (DB) – a diamond bur on a high-speed handpiece; and Group 2 (CVD) – a CVD tip on an ultrasonic handpiece. Each group used 37% phosphoric acid and was divided into three subgroups, according to the etching time (n = 10): Subgroup 5s - 5 seconds; Subgroup 10s - 10 seconds; and Subgroup 15s - 15 seconds. Teeth were restored with Single Bond adhesive and the composite resin Herculite Classic. The specimens were subjected to thermomechanical wear (mechanical cycling/100.000 cycles, thermal cycling/1.000 cycles). Stick-like specimens were obtained and submitted to a microtensile test in a universal testing machine. Data (MPa) were analyzed by two-way ANOVA (Surface treatment X Etching time) and Tukey's test (5%). **Results and Conclusion:** Surface treatment with CVD tips (27.70 ± 4.04a) produced significantly higher bond strength values compared to diamond burs (23.96 ± 5.83b), and 5 s etching time on dentin produced similar bond strength values when compared to 10 and 15 s etching times.

KEYWORDS

Dentin; Tensile strength; Bond; Smear layer.

RESUMO

Objetivo: avaliar a força de união de um adesivo convencional à dentina, usando pontas diamantadas e pontas CVD para preparo dentinário e variando o tempo de condicionamento ácido a dentina. Material e Métodos: A dentina da superfície vestibular de 60 dentes bovinos foi exposta e preparada usando dois diferentes métodos (n=30): Grupo 1 (DB) – ponta diamantada tradicional para alta rotação; e Grupo 2 (CVD) – ponta CVD montada em ultrassom. Cada grupo foi dividido em três subgrupos, de acordo com o tempo de condicionamento ácido (n=10): Subgrupo 5s - 5 segundos; Subgrupo 10s - 10 segundos; e Subgrupo 15s - 15 segundos. Os dentes foram restaurados com adesivo convencional Single Bond e resina composta Herculite Classic. As restaurações foram submetidas à ciclagem termo-mecânica (ciclagem mecânica/100.000 ciclos, ciclagem térmica/1.000 ciclos). Palitos foram obtidos e submetidos ao teste de microtração na máquina de ensaios universal. Os dados (MPa) foram analisados por ANOVA dois-fatores (Tratamento de superfície X Tempo de condicionamento) e teste de Tukey (5%). **Resultado e Conclusão:** O tratamento de superfície com pontas CVD (27.70 ± 4.04a) resultaram em valores de adesão significantemente maiores quando comparados com as pontas diamantadas (23.96 ± 5.83b), e 5 segundos de condicionamento ácido sobre a dentina produziu valores similares de adesão quando comparado aos tempos de 10 e 15 segundos de condicionamento.

PALAVRAS-CHAVE

Dentina, força de união, adesão, camada de esfregaço.

CLINICAL RELEVANCE

CVD tips may favors dentin etching and promote a more effective hybridization, and 5 s etching time maybe is sufficient to promote an efficient bond to dentin.

INTRODUCTION

Almost five decades after the beginning of adhesion use on dental substrates, and with the advancement of technology and scientific knowledge applied to dentistry procedures, the bond to dentin has still been widely questioned, specifically at the gingival margins of adhesive restorations, where the substrate is at the dentin/cement junction is the dentin/cement junction [1]. Dentin is a heterogeneous substrate with a tubular structure and high organic content, and is intrinsically moist [2]. During cavity preparation, a smear layer is deposited on the tooth substrates, and it can be modified according to the rotatory instrument used in cavity preparation [3-6]. The rotatory instrument most commonly used for cavity preparations is the diamond bur. The cavity preparation using diamond burs has advantages such as providing precise cuts, ease of operation, and tactile and visual operator control [4,6]. But, this technology can cause discomfort for the patient because it generates heat, pressure, vibration, and noise, making it difficult to gain the patient's cooperation, especially in pediatric dentistry [6-8].

However, different options besides the traditional cavity preparation with diamond burs have been proposed. The CVDentus® diamond tips are obtained by chemical vapor deposition of a diamond film formed on a metal rod molybdenum [6,9]. These tips are coupled to a Dental ultrasonic device, which allows proper irrigation during cavity preparation and promotes oscillatory movement with effective cleaning power, as the ultrasonic action forms micro-bubbles that collide and release energy and moving particles [9-11]. The cavity preparation with CVD tips has the following advantages: reduced noise, minimal damage to the gingival tissue, superior bur durability, improved proximal cavity access, and conservative cavities (well-defined walls and finishing margins) [6,9-11].

With the advances in microscopy, however, the smear layer morphology became widely analyzed and was shown to possibly affect the bonding procedures [4-6,12]. CVD tips promote intense movement of the particles, which cleans the remaining surface, and partially removes the smear layer, which makes it thinner when compared to the results of using diamond burs [6,9]. It is suggested that the association between CVD tips on tooth preparation and self-etching adhesives [5,6,8] and between CVD tips with total-etching adhesives, reduces the application time of phosphoric acid on the dentin [13]. The total-etch completely removes the smear layers and demineralizes the adjacent dentin [14]. The collagen network with low mineral content is exposed, allowing the infiltration of resin through the nanometric spaces, originating in the hybrid layer, which is responsible to micro-mechanical interlocking between the adhesive and dentin [2,3,15]. The total-etch technique continues to be the one most frequently used by clinicians. Even with the improvements in self-etching adhesives, the results in the literature are still very controversial with regard to their clinical longitudinal effectiveness [3,15].

The CVD tips used for cavity preparation produce distinct grinding patterns and dentin surfaces with different characteristics, both of which may influence the bond strength of total-etch adhesives. Thus, the aim of this study was to investigate the effect of two different methods of dentin preparation and the variation of etching time on dentin bond strength using total-etch adhesives. This study tested two null hypotheses: 1) the surface dentin preparation with CDV tips or diamond burs can achieve similar bond strengths to dentin; and 2) the etching time does not affect the bond strengths to dentin.

MATERIAL AND METHODS

The roots of sixty freshly extracted bovine incisors were sectioned with a steel diamond disc (KG Sorensen, Rio de Janeiro, Brazil) at the cement/enamel junction. The roots were discarded and the buccal surfaces were abraded (240 grit abrasive paper) using a circular polishing machine (PA-10; Panambra, SP, Brazil) under water-cooling to obtain a 5 X 5 mm area of flat dentin. The specimens were embedded with autopolymerizing acrylic resin. The smear layer was standardized using 600 grit abrasive papers coupled to a circular polishing machine (PA-10; Panambra) under water-cooling for 10 s.

The teeth were randomly divided into two groups (n=30), according to the surface treatment performed:

Group DB: The surface treatment was performed with conventional diamond bur #3098 (KG Sorensen, Barueri, SP, Brazil), mounted in a dental turbine (Super Torque, Kavo, Joinvile, SC, Brazil) at high-speed under water-cooling. All surface treatments were prepared by the same operator. The burs were used 15 times mesio-distally and 15 times cervicoincisally, to standardize the thickness of wear [6].

Group CVD: The CVDentus® tip C1 (CVDentus, São José dos Campos, SP, Brazil) was coupled in an ultrasound device (CVDent 1000®; CVDentus, São José dos Campos, SP, Brazil), both under water-cooling. The parameters used were as follows: 30 kHz; 8 W; 120 ml/min rate of water flow; and 70% maximum power. The pattern of wear was performed in the same manner described above for the diamond bur, under copious air-water spray [6].

The groups were divided into three subgroups (n = 15), according to the etching time:

Subgroup 5s: The surfaces were etched for 5 s with 37% phosphoric acid gel (Condac 37/FGM), rinsed for 20 s, and the excess moisture was removed with absorbent paper;

Subgroup 10s: The surfaces were etched for 10 s with 37% phosphoric acid gel (Condac 37/FGM), rinsed for 20 s, and the excess moisture was removed with absorbent paper;

Subgroup 15s: The surfaces were etched for 15 s with 37% phosphoric acid gel (Condac 37/FGM), rinsed for 20 s, and the excess moisture was removed with absorbent paper.

Two layers of Single Bond adhesive (3M ESPE, St. Paul, MN, USA) were applied on the surface actively for 15 s and air dried for 10 s. The adhesive was light activated for 10 s with a LED light unit (Radii cal; SDI, Victoria, Australia; power density = 500 mW/cm2). Restorations were made with a composite resin (Herculite Classic; Orange, CA, USA), using a silicon matrix (4x4x4 mm) as recommended by the manufacturer. Two 2 mm^2 increments were cured for 40 seconds each (Radii cal; SDI). The trade name, chemical composition, and manufacturer of the materials used are presented in Table 1.

Table 1 - Clinical appearance of the lesion. Large mass of soft tissueon right hard palate

Material	Manufacturer	Composition
Condac 37	FGM, Joinville, SC, BRAZIL	37 % phosphoric acid
Single Bond 2	3M ESPE, St.Paul, MN, USA	Bis-GMA, HEMA, dimethacrylate, methacrylate functional copolymer of polyacrylic and polytaconic acid, water, alcohol, photoinitiator
Herculite Classic	Kerr, Orange, CA, USA	Bis-GMA, TEGDMA, photoinitiator, Amina, Iron Oxide Pigment, glass borosilicate Aluminum, Colloidal Silica.

Bis-GMA, bisphenol A glycidyl methacrylate; HEMA, bisphenol A glycidyl methacrylate; TEGDMA, triethylene glycol-dimethacrylate

After restorative procedures, specimens were stored in deionized water in a dry oven at 37°C for 24 h. Artificial aging was accomplished through thermomechanical attrition 37000

(ERIOS ER – 37000, São Paulo, SP, Brazil). 100,000 mechanical cycles (60 cycles per minute) were performed with a mechanical load of 60 N applied perpendicularly to the restoration long axis, and 1,000 thermal cycles (30 s each) were performed in deionized water (5°C, 37°C, and 55°C).

Specimens were longitudinally sectioned in both "x" and "y" directions (Labcut 1010; Extec Corp., Enfield, CT, USA) into sticks measuring approximately 1 mm2 (about seven sticks per tooth). Each stick was submitted to a microtensile bond strength test using a universal testing machine (DL 200MF; Emic, São José dos Pinhais, SC, Brazil) with a 10 kg load cell, at a crosshead speed of 0.5 mm/min, in accordance with the ISO 11405 Standard.

Pre-testing failures were discarded. The bond strength values were expressed in MPa. The comparison between the groups was done using the mean of each tooth. The data were subjected to two-way ANOVA (Surface treatment X Etching time) and Tukey's test, with a significance level of 5%.

Two teeth from each group were prepared for SEM analysis according to Marimoto et al. [16].

RESULTS

Mean (in MPa) and standard deviation data for all groups/subgroups are shown in Table 2.

Two-way ANOVA (Table 3) showed significant differences for Surface treatment factor ($p < 0.05$). The Group CVD, which promoted surface treatment with CVD tips (27.70±4.04a), presented higher bond strength values compared with Group DB, which promoted surface treatment with diamond burs (23.96±5.83b) (degree of freedom: 1; f: 8.08; p: 0.0063). Therefore, the first null hypothesis tested was rejected because surface treatment with CVD tips showed higher bond strength values when compared to surface treatment with diamond burs.

For the Etching time factor and Interaction between the factors, the results showed an absence of significant differences between groups ($p > 0.05$). Therefore, the second null hypothesis tested was accepted because there was no difference in bond strength values between the three different etching times of the dentinary substrate.

Table 3 - Results of Two-way ANOVA

Effect	Degree of freedom	f	p
Surface treatment	1	8.08	0.0063*
Etching time	2	0.28	0.7585
Interaction	3	0.80	0.4547

*(Satistical differences)

Examination of sticks after failure indicated predominantly adhesive and mixed failure for all groups (>95%). Figures 1 - 5 show SEM images obtained from the surfaces created in all the groups.

Table 2 - Mean (in MPa) and standard deviation data and results for all group/subgroup

Etching-time (Subgroup)	Surface treatment (Group)		
	Diamond Bur	CVD Tip	(Line) Mean
5 s	24.73±5.58a	26.80±3.87a	25.76±4.79a
10 s	24.89±5.83a	28.03±3.83a	26.46±5.07a
15 s	22.25±6.29a	28.27±4.64a	25.26±6.20a
(Column) Mean	23.96±5.83a	27.70±4.04b	

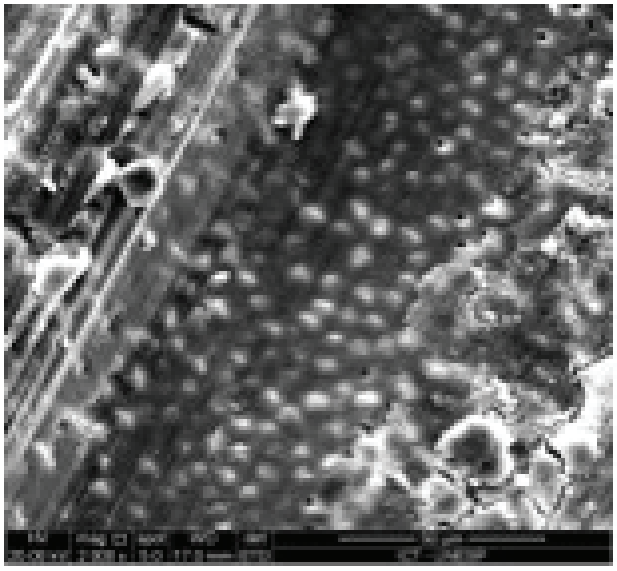

Figure 1 - Surface prepared with CVD tip (2000X). Some dentin tubules partially opened and a thin smear layer.

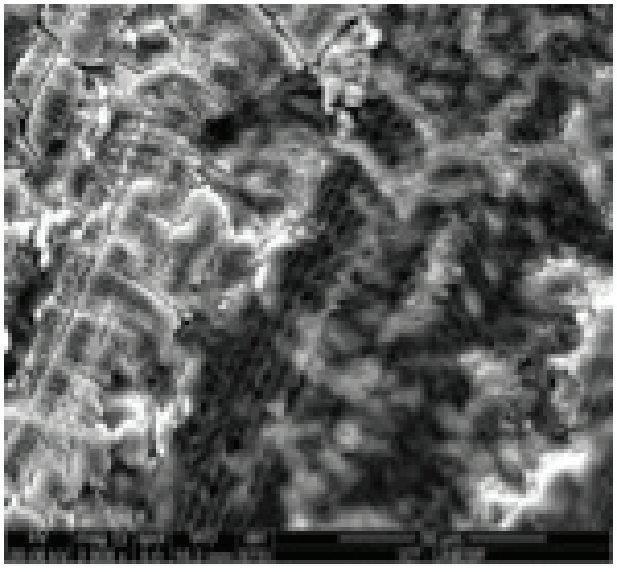

Figure 1 - Surface prepared with diamond bur (2000X). Dentin tubules totally obliterated and a thick smear layer.

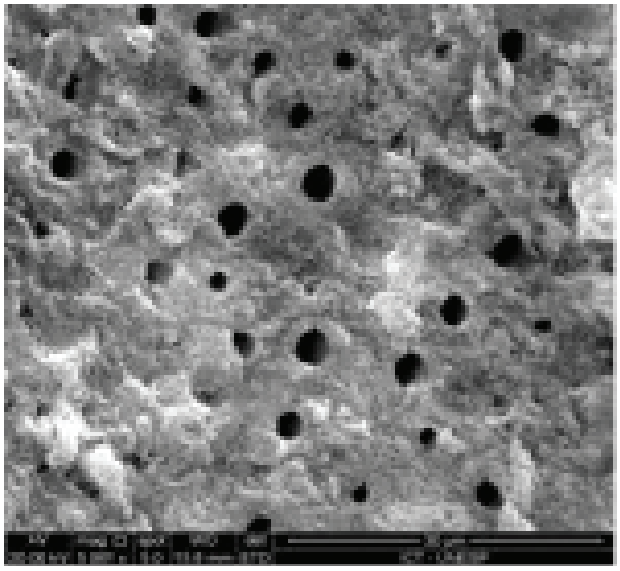

Figure 3 - Surface conditioned for 5 s (5000X). Few open dentin tubules with presence of a thin smear layer.

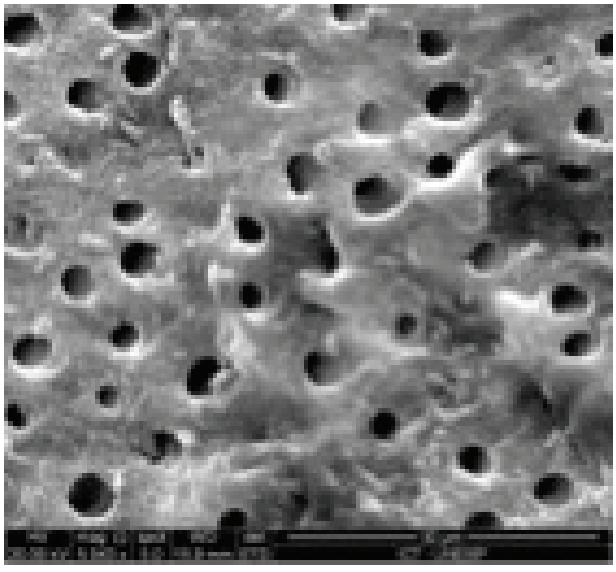

Figure 4 - Surface conditioned for 10 s (5000X). Many open dentin tubules, partially desobliterated with presence of a thin smear layer.

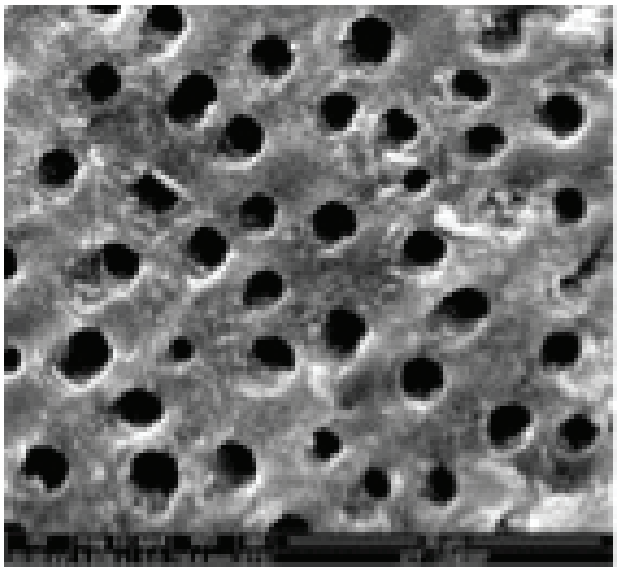

Figure 5 - Surface conditioned for 15 s (5000X). Dentin tubules totally desobliterated.

DISCUSSION

A smear layer is necessarily formed after cavity preparation [17,18]. The amount of smear layer produced is dependent on the type of instrument and water-cooling used, which are relevant in choosing the adhesive system that will be used to restore the cavity [19].

In this study, CVD tip innovative technology used for cavity preparation produce distinct grinding patterns on the dentin surfaces [6], which can positively influence the dentin bond strength of Single Bond adhesive system. CVD tips allow proper irrigation during cavity preparation and the oscillatory movement of the dental ultrasonic device forms air micro-bubbles inside the liquid of the irrigation [6]. Some micro-bubbles can grow and implode when in contact with the dental surface, liberating a great amount of energy [6]. This energy may remove part of the smear layer and contributing to an effective cleaning preparation [9-11]. This causes a greater number of opened dentinal tubules [9,11], which may have favored dentin etching, allowing ions from removing the calcium present and partially exposing the extensive collagen mesh more effectively. Consequently, Single Bond may have promoted a more effective hybridization with an improved bond when compared with diamond burs. This study results contradict the findings of Cardoso et al. [5] and Silva et al. [6], who observed better bond strength results of total-etching adhesives when they were used with diamond burs compared to CVD tips.

Better results for CVD tips when compared to diamond burs were confirmed by SEM analysis. CVD tip presented a dentin-prepared surface with grooves, an irregular smear layer, and partially opened dentin tubules, which resulted from the lower amount of smear layer (Figure 2). This surface characteristic occurred probably due the cleaning ability of the cavitation phenomenon produced by ultrasonic vibrations that forms the micro-bubbles [6].

Whereas, it was observed that the diamond bur presented a uniformly scratched surface, a large amount of smear layer, and partially or totally obliterated tubules (Figure 1). Probably these grinding patterns and smear layer characteristics resulted in different interactions with Single Bond adhesive system, affecting negatively the dentin bond strength results when compared to CVD tip.

The study findings showed that the 5 s of etching presented similar bond strength to dentin when compared to 10 and 15 s of dentin etching. These results were surprising, because the 15 seconds of etching of dentin substrate is consecrated by dental literature. However, observing the SEM analyzes, there can be seen a gradual increase of the smear layer removal and pattern of the opening of dentinal tubules as the etching time increases (Figures 3, 4, and 5). The etching of dentin substrate is a stage that greater errors can occur during an adhesive restoration. These bond strength results can suggest that 5 seconds etching time is sufficient to promote an efficient bond to dentin. Consequently, this protocol may decrease the formation of a deep zone of demineralized dentin with regions of exposed collagen fibers not infiltrated by

adhesive, which is more susceptible to hydrolysis (weak zone) [20].

The study findings confirm the importance of knowledge of the interaction between new technologies and dental materials in order to obtain higher bond strength between dentin and composite resins. However, it is necessary to conduct longitudinal research to observe the longevity of the dentin bond strength using the CVD technology, and if the 5 s etching time can reduce the hydrolysis of the adhesive interface over time.

CONCLUSION

From the results obtained, it can be concluded that the surface treatment with CVD tips was promising in increasing the bond strength compared to the surface treatment with diamond burs and etching the dentin surface for 5 s seems to be effective to achieve desirable adhesive strength.

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