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# The effect of sandblasting distances on the shear bond strength of a self-etch and total-etch adhesive system to cervical dentin in the gingival wall of Class II restorations

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## ABSTRACT

**Background:** This study aimed to examine the effect of sandblasting on the shear bond strength (SBS) of two adhesive systems on cervical dentin in the gingival wall of Class II restorations at two different distances.

**Materials and Methods:** In this *in vitro* study, 88 intact premolars were used. After creating a natural smear layer, samples were divided into self-etch (CLEARFIL LINER BOND F) and total-etch (Adper Single Bond 2) groups ($n = 44$). Each group was subdivided into subgroups ($n = 22$) for sandblasting at 5 mm or 10 mm, with the contralateral half as control. Following sandblasting (50-µm particles, 2 bar, 2 s), the resin composite was bonded to the dentin surface, with the SBS of the samples measured using a universal testing machine. The samples were examined using a scanning electron microscope (SEM) and analyzed by an energy dispersive X-Ray (EDX). The results were analyzed using three-way repeated measures analysis of variance and Chi-square tests ($\alpha = 0.05$).

**Results:** Sandblasting significantly reduced the SBS in both adhesive groups ($P < 0.001$). However, the adhesive system and distance did not significantly affect the bond strength ($P > 0.05$). The SEM images displayed the formation of irregularities in the smear layer, and EDX analysis revealed the presence of residual alumina particles on the blasted dentin samples.

**Conclusion:** Cervical dentine sandblasting reduced the adhesive SBS regardless of the 5- or 10-mm distance or the adhesive system used. Thus, sandblasting is not recommended as a method of dentin preparation before restoring cervical lesions.

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**Key Words:** Air abrasion, dental, dental bonding, dental cavity preparation, dental restoration, permanent

## INTRODUCTION

Preservation of the remaining tooth structure, esthetics, function, and prevention of microleakage are essential characteristics of ideal restorations.[1] Over the past few decades, there has been a heavy focus on improving the esthetics of tooth restorations, leading to the development of new dental materials

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and clinical techniques. Adhesive materials have emerged as a solution to enhance esthetics, durability, and minimize invasiveness.[2] Among the various restoration materials, composite restorations have gained significant popularity thanks to the growing demand for cosmetic treatments in recent years.[3] One of the key features of these restorative materials is their ability to bond and establish a connection with the remaining tooth structure. However, achieving successful bonding with resin-based adhesives poses challenges for dental tissues.[4]

The bonding process involves replacing the minerals lost from the hard tissue with resin monomers, creating adhesion through chemical bonds and micromechanical interlocking, forming what is known as the hybrid layer.[5] The performance of adhesive restorations is influenced by several factors, including the adhesive technique used, the quality and materials of the restoration, the vulnerability of the adhesive surface to oral fluids, and the treatment of the remaining tooth tissue.[6] Bonding in dentin presents more challenges than in enamel due to the lower mineral content in dentin.[7]

The adhesive bond strength of resins to dentin depends not only on the quality of the materials used but also on various factors, including calcium concentration, proper isolation, and the depth of dentin.[8] Deep dentin poses a particular challenge due to the lack of intertubular dentin and the presence of a large amount of water in the dentin tubules, which reduces the strength of the bond.[9]

Class II restorations are especially critical in this context. Gingival walls in Class II restorations are prone to producing gaps, increasing the risk of restoration failure and secondary caries. The tooth anatomy in this area, with higher dentinal tubule density near the CEJ, exacerbates the issue. Moisture from the pulp moves toward the dentin surface after acid-etching, leading to challenges in hybrid layer formation, susceptibility to hydrolytic breakdown, and bacterial enzyme penetration, ultimately compromising bond strength and integrity.[10] Investigating surface preparation methods to improve bond quality in this area is therefore crucial for the durability of Class II restorations.

Two groups of dentin adhesive systems, self-etch and total-etch (etch-and-rinse), have experienced significant changes over the years. These two groups have been compared in different studies based on factors such as the thickness of the hybrid layer, sensitivity, durability, and bond strength.[11,12]

Enhancing the contact between dentin and the adhesive surface through mechanical or chemical pretreatments to augment surface roughness can positively affect the adhesion strength of the bonding agent.[2] One way to enhance the bond strength is to increase surface roughness, which can be achieved through sandblasting with 50-μ alumina ($Al_2O_3$) particles.[13] Alumina particles create an active surface that promotes bonding. However, the effectiveness of sandblasting depends on various factors, including particle size, sandblasting time, angle, pressure, etc.[13,14]

Given the numerous advantages and growing demand for composite restorations, as well as the challenging nature of bonding with deep dentin and the availability of different bonding types, there is a need for further research to enhance the bond strength in deep dentin, particularly in the gingival floor of Class II cavities. The present study aimed to compare the impact of sandblasting on the shear bond strength (SBS) of a self-etch and total-etch adhesive system to the gingival floor of Class II cavities at two different distances.

## MATERIALS AND METHODS

### Ethical considerations

This *in vitro* study has been approved by the ethics committee of the Mashhad University of Medical Sciences with the code of IR.MUMS.DENTISTRY.REC.1401.073, following the Declaration of Helsinki.

### Preparation

A total of 88 human premolar teeth that were extracted for orthodontic reasons and showed neither restoration nor decay were selected. The teeth were cleaned and kept in chloramine t (Merck, Darmstadt, Germany) for 3 days. The teeth were mounted in self-cure acrylic resin (Acropars 200, Tehran, Iran), after which the samples were trimmed to the CEJ so that no enamel was left at the margin. Before the sandblasting procedure, the teeth were kept in physiological saline at room temperature for 3 days.

### Sandblasting treatment procedure

Before sandblasting, to create a natural smear layer, the smear layer created by trimming was first removed using ethylenediaminetetraacetic acid (EDTA) 17% (Morvabon, Tehran, Iran), and then, the natural smear layer was created using silicon carbide P600 (Matador, Remscheid, Germany). The teeth were classified into four groups:

a. Self-etch (SB), sandblasting at a distance of 5 mm (*n* = 22)
b. Self-etch (SB), sandblasting at a distance of 10 mm (*n* = 22)
c. Total-etch (CL), sandblasting at a distance of 5 mm (*n* = 22)
d. Total-etch (CL), sandblasting at a distance of 10 mm (*n* = 22).

In each group, the tooth's buccal or lingual half was randomly selected for sandblasting using a sandblasting device (RØNVIG Dental Mfg. A/S Daugaard, Denmark). The opposite side of each sample, which did not undergo sandblasting, served as the control for that particular sample. All control areas were covered with isolation tape (TDV Iso tape, Brazil) to protect them during sandblasting. An experienced operator (SG) performed the sandblasting procedure perpendicular to the tooth surface using 50-μ aluminum oxide powder (RØNVIG Dental Mfg. A/S Daugaard, Denmark). The sandblasting process involved linear motion and lasted for 2 s, applying a pressure of 2 bars.

## Bonding

The isolation tape was removed from each sample, followed by a 30 s water rinse and drying with a gentle airflow for 2 s. Next, the self-etch (SB) and total-etch (CL) adhesives were applied per the manufacturer's instructions. In the SB groups (*n* = 44), CLEARFIL LINER BOND F Adhesive (Kuraray Noritake Dental Inc, Tokyo, Japan) was actively applied using a micro brush for 20 s. A strong airflow was used to create a uniform and thin layer, removing any excess solution and evaporating the solvents. Subsequently, it was cured using the light cure device (Bluephase C8, Ivoclar Vivadent, Schaan, Liechtenstein) for 10 s. Adper Single Bond 2 Adhesive (3M, St. Paul, MN, USA) was utilized in the CL groups (*n* = 44). First, phosphoric acid (35%) (3M, St. Paul, MN, USA) was applied to the tooth surface for 15 s, followed by a 10-s rinsing to remove the acid. Excess water was carefully removed using cotton to achieve a glossy surface without water accumulation.

Subsequently, the adhesive was applied in two layers using a micro brush, with gentle agitation for 15 s to ensure proper coverage. To remove the solvents and create a thin bonding layer, a gentle airflow was applied for 5 s. The final step involved curing the adhesive with a light cure device for 10 s, ensuring optimal bonding and setting of the material.

## Restorative phase

Two plastic tubes, each with a length of 2 mm and a diameter of 1.3 mm (1.32 $mm^2$), were filled with z250 composite (3M, St. Paul, MN, USA). One restoration was placed on the buccal side of the tooth, while the other was placed on the lingual side. Both restorations were cured for 20 s by a trained operator (SG) to ensure proper setting.

Following the curing process, the samples were carefully placed in physiological saline at room temperature and left to undergo a 24-h polymerization reaction. This 24-h period would allow the composite material to fully set and achieve its optimal physical properties.

## Evaluation of shear band strength and failure type

The SBS of the samples was evaluated using a Universal Testing Machine (SANTAM Eng. Design Co. Ltd., Tehran, Iran) with a crosshead speed of 1 mm/min. This testing method allowed for accurate measurement of the bond strength between the materials.

To assess the type of fracture that occurred during the testing process, the surface of the specimens was carefully examined under a stereomicroscope (Dino-Lite, AnMo Electronics Corporation, Taiwan) at ×25. The type of fracture observed in each sample was recorded and categorized as follows:

- Adhesive: The fracture occurred at the adhesive interface between the tooth surface and the bonding agent
- Cohesive fracture in teeth: The fracture occurred within the tooth structure itself, indicating the strength of the natural tooth material
- Cohesive fracture in composite: The fracture occurred within the composite material, highlighting its bonding strength to the tooth structure
- Mixed failure: A combination of adhesive and cohesive fractures was observed, indicating multiple failure points within the bonded interface.

By categorizing the type of fracture, the study could gain valuable insights into the bond integrity and performance of the different materials used in the dental restoration process.

### Scanning electron microscope and energy dispersive X-ray analysis

Scanning electron microscope (SEM) and energy dispersive X-Ray (EDX) were conducted to assess the surface characteristics and chemical composition of the samples. Following the sandblasting process, one sample from each group (from the original samples) was carefully selected for SEM analysis (XL30, FEI, Hillsboro, USA). The samples were observed at various magnifications, with a voltage of 10 kV applied during the imaging process. The samples were gently divided into two pieces from the center using a wedge with a controlled vertical force applied perpendicularly to the occlusal surface, to examine the level and cross-section of the lateral exposure of the dentinal tubules. In addition, sample polishing was avoided due to the importance of maintaining the surface quality. To enhance imaging quality, the samples were coated with a thin layer of gold before analysis.

In addition to SEM, the chemical composition of the samples' surfaces was evaluated using EDX analysis (XL30, FEI, Hillsboro, USA). EDX provided valuable insights into the elemental composition of the surfaces, aiding in understanding the materials' bonding and interactions.

To further investigate the impact of variables involved in the study, three separate samples (extra samples) were prepared. These additional samples were subjected to SEM analysis to explore the surface dimensions after specific treatments:

- Full surface sandblasting from a distance of 5 mm
- Full surface sandblasting from a distance of 10 mm
- Control surface (without sandblasting).

Each of these individual samples underwent an additional treatment to assess the effect of the total-etch group's phosphoric acid application and the self-etch group's acidic primer application. The buccal side of the samples was exposed to 35% phosphoric acid, while the lingual side was exposed to an acidic primer during the testing.

Using SEM and EDX analysis, the surface morphology and chemical interactions of the samples were characterized, helping to inform the findings and conclusions of the research.

### Statistical analysis

Data analysis was performed using SPSS version 25 (IBM Corp., Armonk, NY, USA) and Prism-GraphPad version 9 software (GraphPad Software, Inc; CA, USA). Descriptive data analysis and coefficient of variation (CV) tests were conducted to examine the variability and characteristics of the data. To assess the effects of multiple variables simultaneously, a three-way repeated measures analysis of variance (ANOVA) with a 95% confidence interval was utilized. The significance level below 5% ($P < 0.05$) was considered to determine statistical significance, ensuring robust and reliable results in the study.

## RESULTS

### Shear bond strength results

In Table 1, the descriptive analysis of the data revealed that the average strength of the SBS diminished with sandblasting, and this effect was more pronounced in the self-etch adhesive group. In addition, the CV% rose by 8%–10% in all groups, except for the CL10 group. Interestingly, in the CL10 group, unlike the other groups, the CV dropped by 9% after sandblasting [Table 1].

Regarding SBS, it was observed that the CL5 group experienced a reduction of 36.6%, the CL10 group a decline of 27.2%, the SB5 group a decrease of 18.6%, and the SB10 group a drop of 21.3%. Notably, the results demonstrated that the reduction in bond strength due to sandblasting was more substantial in the CLEARFIL LINER BOND F group compared to other groups [Table 1 and Figure 1].

The sandblasting factor, considered as a within-group variable, had a significant impact on the average SBS ($P < 0.001$), leading to a decline in bond strength. However, the combined effects of sandblasting and

**Table 1: Mean±standard deviation (MPa) and coefficient of variation percentage of the experimental and control groups of the study according to the adhesive used and sandblast distance**

| Adhesive | Distance (mm) | Group | Mean±SD (MPa) | CV% |
|---|---|---|---|---|
| CL bond F | 5 | Control | 19.97±8.02 | 40 |
| | | Sandblasted | 12.65±6.03 | 48 |
| | 10 | Control | 19.68±8.84 | 45 |
| | | Sandblasted | 14.33±5.24 | 36 |
| SB | 5 | Control | 18.34±8.05 | 44 |
| | | Sandblasted | 14.92±7.72 | 52 |
| | 10 | Control | 19.58±8.17 | 42 |
| | | Sandblasted | 15.41±8.20 | 52 |

SB: Single bond; CL: CLEARFIL LINER; SD: Standard deviation; CV: Coefficient of variation distance ($P = 0.81$), sandblasting and adhesive type ($P = 0.33$), as well as the combined effect of all three variables (sandblasting × distance × adhesive type), were not found to be statistically significant ($P = 0.60$) [Table 2].

Similarly, as indicated in Table 3, none of the variables of distance ($P = 0.39$), type of adhesive ($P = 0.90$), and the combined effect of these two ($P = 0.89$) demonstrated any substantial effect on the bond strength [Table 3].

**Table 2: Three-way repeated measures ANOVA – within-groups test**

| Source | df | Sum of squares | Mean square | *F* | *P** |
|---|---|---|---|---|---|
| Sandblasting | | | | | |
| Sphericity assumed | 1.00 | 974.211 | 974.211 | 15.367 | 0.000** |
| Sandblasting × distance | | | | | |
| Sphericity assumed | 1.00 | 3.575 | 3.575 | 0.056 | 0.813 |
| Sandblasting × adhesive | | | | | |
| Sphericity assumed | 1.00 | 61.025 | 61.025 | 0.963 | 0.330 |
| Sandblasting × distance × adhesive | | | | | |
| Sphericity assumed | 1.00 | 17.591 | 17.591 | 0.277 | 0.600 |
| Error (sandblasting) | | | | | |
| Sphericity assumed | 1.00 | 4627.921 | 4627.921 | - | - |

*3-way repeated measures ANOVA; ***P*<0.05 is considered significant

**Table 3: Three-way repeated measures ANOVA – between-groups test**

| Source | df | Sum of squares | Mean square | *F* | *P** |
|---|---|---|---|---|---|
| Distance | | | | | |
| Sphericity assumed | 1.00 | 41.188 | 41.188 | 0.735 | 0.394 |
| Adhesive | | | | | |
| Sphericity assumed | 1.00 | 0.882 | 0.882 | 0.016 | 0.900 |
| Distance × adhesive | | | | | |
| Sphericity assumed | 1.00 | 1.091 | 1.091 | 0.019 | 0.889 |
| Error | | | | | |
| Sphericity assumed | 1.00 | 4144.885 | 4144.885 | - | - |

*3-way repeated measures ANOVA

## Type of failure

Figure 2 depicts the frequency distribution of the type of failure on the control side of each group. The predominant type of failure observed in all groups was adhesive failure. However, interestingly, at a distance of 5 mm in the SB group, no dentine cohesive failure was observed. Cohesive composite failure, on the other hand, was observed exclusively in the samples that underwent sandblasting at a distance of 10 mm [Figure 2].

Figure 3 illustrates the frequency distribution of fracture types on the sandblasted side. Consistent with the findings on the control side, the most common type of failure in all groups was adhesive failure. However, notably, at a distance of 10 mm in the CL group, no dentin cohesive failure was observed. In contrast, cohesive composite failure was observed exclusively in the samples that underwent sandblasting at a distance of 5 mm [Figure 3].

The Chi-square test was conducted to assess the impact of sandblasting on the frequency distribution of fracture types [Figures 2 and 3] among different groups. The results revealed that in the CL5 group, sandblasting had no statistically significant effect on the distribution of fracture types ($P = 0.003$) [Table 4].

## Scanning electron microscope and energy dispersive X-ray

In the preliminary investigations (original samples) conducted using SEM, the images in Figure 4 reveal the formation of the smear layer in the sandblasted groups at distances of 5 and 10 mm, viewed at magnifications of ×300 and ×5000.

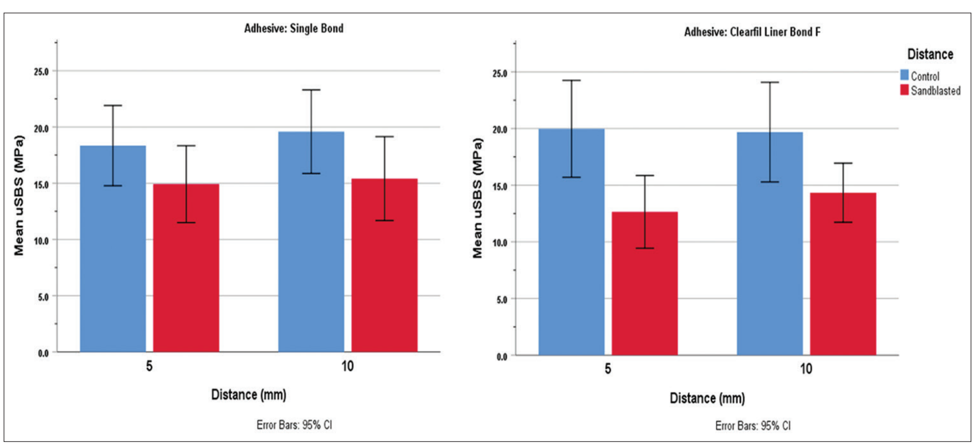


**Figure 1*:*** Shear bond strength (MPa) of the experimental and control groups of the study and according to the adhesive used and sandblast distance (mm)

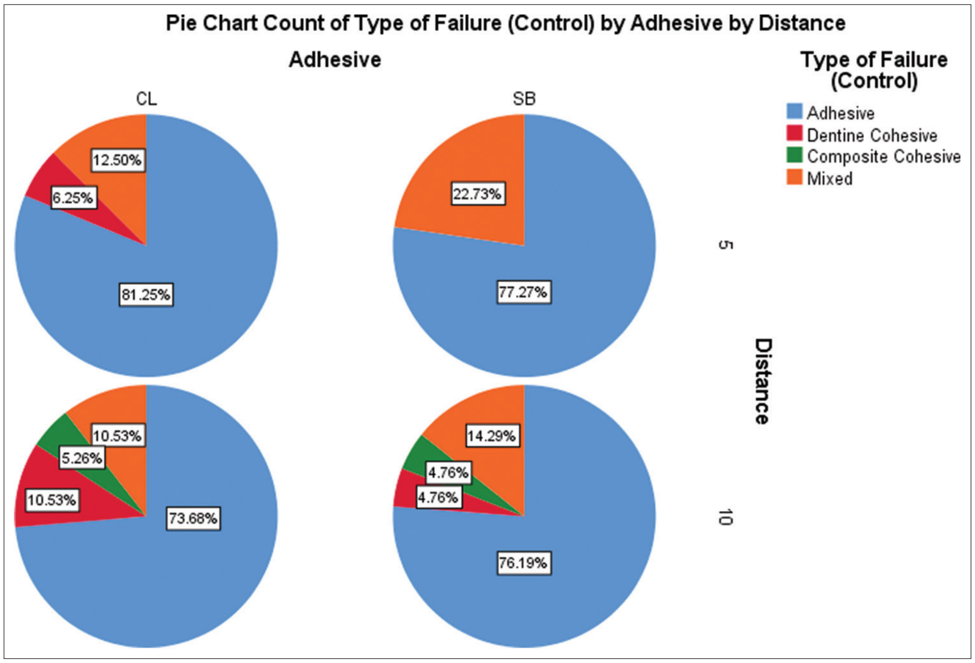


**Figure 2:** Frequency distribution (%) of fracture type on the control side of the study groups (color figure)

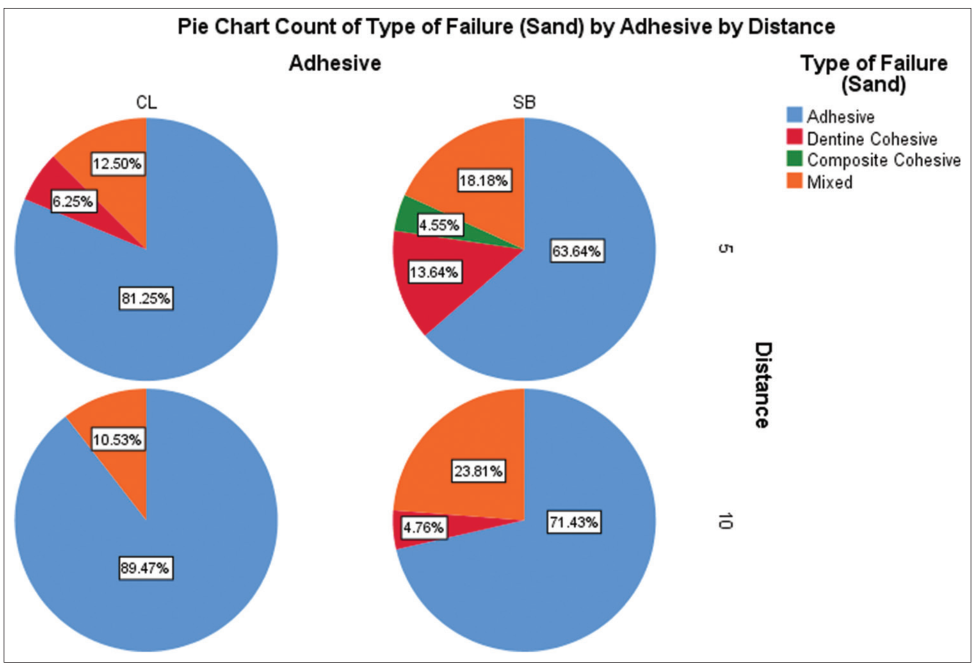


**Figure 3*:*** Frequency distributions (%) of fracture type on the sandblasted side of the study groups (color figure)

The images reveal changes in the smear layer characterized by multiple layers, depressions, and grooves in various shapes and dimensions. Notably, between the 5-mm and 10-mm sandblasting groups, the opening of the dentinal tubules appears more occluded in the 5-mm group [Figure 4a and b]. In addition, microcracks within the underlying dentin structure are evident in Figure 4e (white arrow).

In Figure 5, samples were observed in the lateral section under ×1000. A comparison between the sandblasted groups [Figure 5a, c, e, and g] and the nonsandblasted groups [Figure 5b, d, f, and h] indicates that the sandblasted surfaces show blocked tubule openings by approximately 2–20 µ. Conversely, in Figure 5f, the nonsandblasted surface, prepared by acid etching, displays fully open tubule openings.

Further examination of the images reveals some interesting observations. In Figure 5c (white arrow, c), the penetration of acidic primer is observed in the 5-mm sandblasting group. The approximate thickness of the acidic primer appears to be around 2 μ, as shown in Figure 5h (white arrow, h).

Further, the sandblast particles seem to have penetrated the tubules to a depth of 20 μ in the 10-mm sandblasting group with acid primer surface preparation, as shown in Figure 5g (white arrow, g).

Based on EDX analysis, the presence of more aluminum was observed in the sandblasted groups from a distance of 5 mm, indicating that a greater amount of alumina particles remained on the surface when sandblasting was performed at a closer distance. Furthermore, the graph shows that despite covering the surface of the control group with isolation tape, some aluminum was also detected on the control group [Figure 6].

**Table 4: Chi-square test to compare the frequency distribution of failure types in different groups**

| Adhesive | Distance (mm) | *P** |
|---|---|---|
| CL Bond F | 5 | 0.003** |
| | 10 | 0.850 |
| SB | 5 | 0.586 |
| | 10 | 0.978 |

*Pearson's Chi-square test; ***P*<0.05 is considered significant. SB: Single bond; CL: CLEARFIL LINER

In the SEM examination of three separate samples, Figure 7 shows the surface section of the control group at a magnification of 1000. In Figure 7a, the buccal surface of the teeth is visible (acid-etched), revealing a scattered smear layer and some extent of smear plugs (white arrow, a). However, the opening of the dentinal tubules is fully observable. Figure 7b reveals the lingual surface of the control group, where fewer dentinal tubules are observed compared to the buccal samples. As indicated in the lateral sections [Figure 5], the spherical particles appear to be remnants of the acidic primer that penetrated the dentinal tubules, leading to their closure [Figure 7b, white arrow].

In Figure 8, the surface sections of the sandblasted samples (extra samples) in the 5-mm and 10-mm groups are indicated at a magnification of ×1000. The observations reveal that the samples sandblasted at

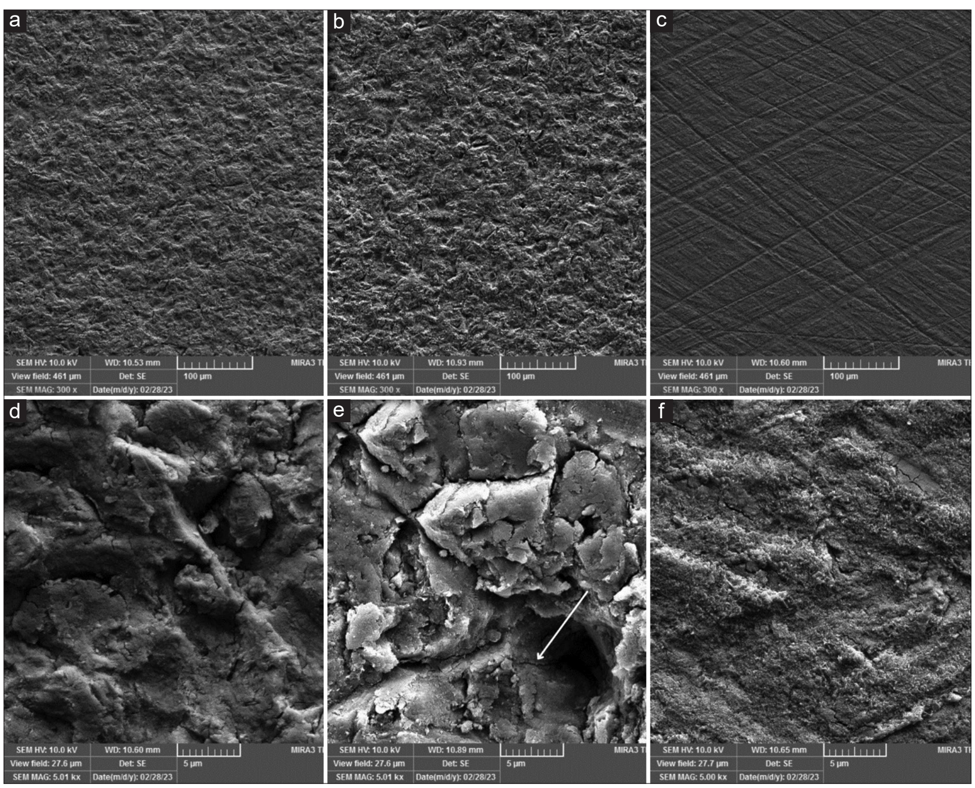


**Figure 4:** Image of two sandblasted groups in different magnifications: (a) sandblasted at a distance of 5 mm with ×300; (b) sandblasted at a distance of 10 mm with ×300; (c) control surface with ×300; (d) sandblasting at a distance of 5 mm with ×5000, The white arrow points to microcracks in the underlying dentin structure; (e) sandblasting at a distance of 10 mm with ×5000; (f) control surface with ×5000

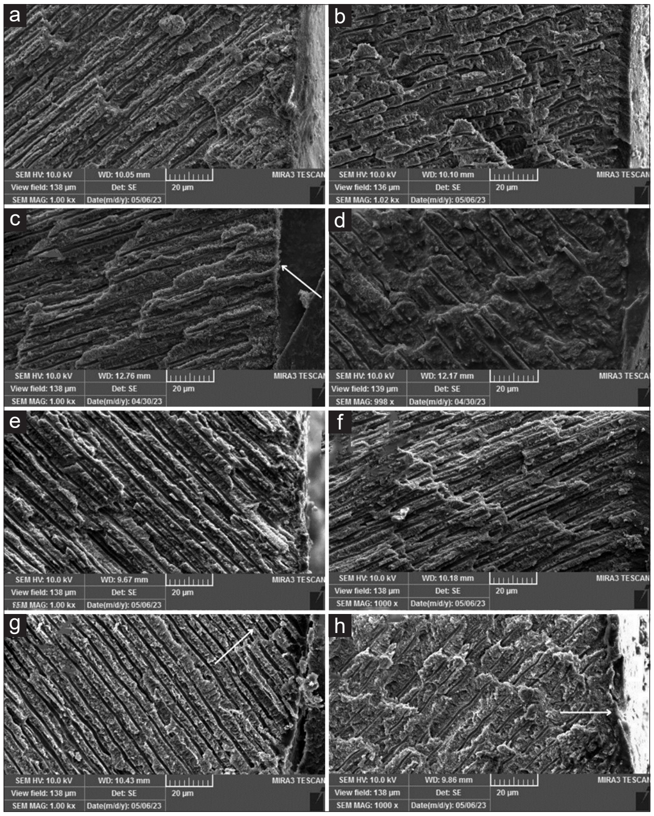


**Figure 5:** SEM image of the samples from the lateral view with ×1000: (a) sandblasted group from a distance of 5 mm with H-acid etch surface preparation; (b) nonsandblasted group from a distance of 5 mm with acid etch surface preparation; (c) sandblast group from a distance of 5 mm with acid primer surface preparation (white arrow); (d) non-sandblast group from a distance of 5 mm with acid primer surface preparation; (e) sandblast group from a distance of 10 mm with acid etch surface preparation; (f) non-sandblast group from a distance of 10 mm with acid etch surface preparation; (g) sandblast group from a distance of 10 mm with acidic primer surface preparation, Sandblasting particle penetration (white arrow); (h) nonsandblast group from a distance of 10 mm with acid primer surface preparation, Penetration depth 2 µ (white arrow)

a distance of 5 mm [Figure 8a and b] had a higher number of occluded tubular openings compared to the 10-mm group (particularly on the acid-etched side). However, it appears that the surface of the 10-mm sandblasted samples had more microcracks, especially on the acid-etched side [Figure 8c, white arrow]. On the surfaces of the teeth bonded by the self-etching system [Figure 8b and d], despite having more tubule entrances than the buccal side, smear layer and spherical particles were still visible.

EDX analysis of extra sandblasted samples is mentioned in Figure 9. In the group that was sandblasted at a distance of 5 mm, the aluminum peak shown in the graph was similar after using 37% phosphoric acid or acid primer. However, in the group that was sandblasted at a distance of 10 mm, the peak of aluminum shown in the graph was different after using 37% phosphoric acid or acidic primer, and it seems that acidic primer showed better ability in irrigating alumina [Figure 9].

## DISCUSSION

Despite being popular restorative materials, composite resins have certain limitations that restrict their widespread usage. These limitations include issues related to their physical properties, such as polymerization shrinkage and microleakage, as well as challenges with wear resistance and color stability. Further, composite resins exhibit lower bond strength to dentin compared to enamel.[8,15]

The differences in enamel and dentin bonding can be attributed to their distinct organic and inorganic compositions. In particular, deep dentin poses specific challenges due to the lack of intertubular dentin and the presence of a significant amount of water in the dentin tubules, both of which contribute to a reduction in the strength of the bond.[16,17] However, it is important to acknowledge that Class II restorations pose additional challenges to achieving strong bond strength in gingival walls due to various risk factors. These factors include the presence of sclerotic dentin, the unique structure and direction of dentinal tubules of cervical dentin, and the higher concentration of intratubular fluid in this region.[18]

A meta-analysis conducted by Lima *et al*.[14] explored various sandblasting conditions, such as particle size, pressure, and control groups, in 33 different studies. The results of this analysis indicated that sandblasting does not have a detrimental effect on the bond strength of resin-based materials to dentin. Indeed, the bond strength grows when the particle size exceeds 30 µ and the pressure exceeds 5 bar.[14] The current study revealed that sandblasting had a significant effect on the average SBS, leading to a reduction in SBS. This highlights the impact of sandblasting on the bond strength of the materials studied.

Rafael *et al*.[19] explored the effects of different surface preparation methods, including acid etching and sandblasting, on the smear layer. The results demonstrated that both acid-etching and sandblasting effectively removed the smear layer. Phosphoric acid was found to create a uniform and regular surface while dilating the dentine tubules, providing

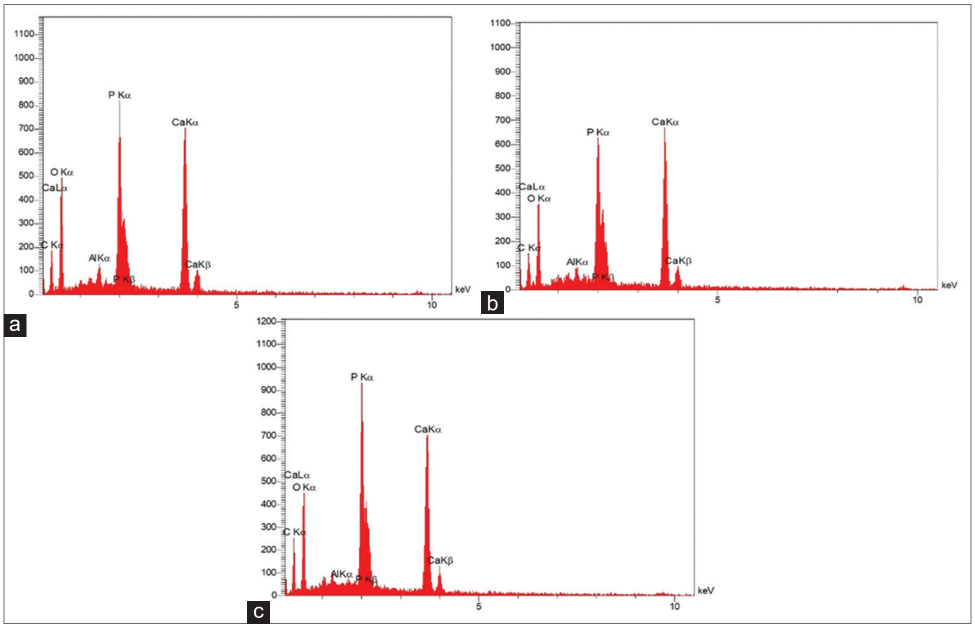


**Figure 6*:*** Energy dispersive X-ray (EDX) diagram of experimental (a and b) and control group (c): (a) EDX diagram of 5 mm sandblasted group; (b) EDX diagram of 10-mm sandblasted group; (c) EDX diagram of control group

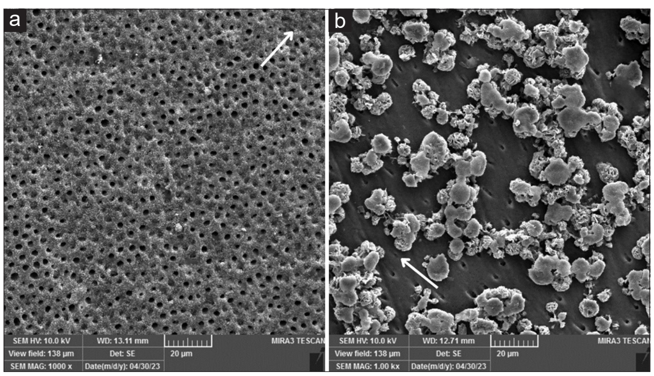


**Figure 7*:*** SEM image of extra samples (control group) from the surface view at ×1000: (a) control group with acid etch surface preparation, scattered smear layer, and some extent of smear plugs (white arrow); (b) control group with acid primer surface preparation, closure of the dentinal tubules (white arrow)

an optimal bonding substrate. On the other hand, sandblasting created a rough and irregular surface, which may have contributed to the reduction in the bond strength observed in the current study. Another factor that may contribute to the reduction of bond strength in the present study is the presence of remaining $Al_2O_3$ particles on the dentin surface. As indicated by the EDX analysis in the present study and supported by other research,[20,21] these $Al_2O_3$ particles can lead to surface contamination and hinder adhesive penetration. Previous studies have shown that attempting to remove these particles using the dental unit's airflow is impractical.[19,22] In the present study, it was evident that neither 35% phosphoric acid or (or not?) acidic primer was able to reduce the amount of $Al_2O_3$ particles to the level seen in the control group. In addition, $Al_2O_3$ particles, being one of the hardest dental abrasive particles, can cause damage to dentin and lead to the formation of microcracks in both enamel and dentin,[21] as observed in our study.

In the study by Freeman *et al*.,[23] they found that sandblasting with 50 µ $Al_2O_3$ particles (using 3 bar pressure, 8 s, and a distance of 2 mm) resulted in the separation of the hybrid layer from the underlying dentin, further supporting the adverse effects of these particles on bonding. However, it is essential to consider that the reduction in the bond strength observed in our study could also be attributed to other factors, such as the presence of bubbles during composite placement inside the tubes, regional variations in the substrate, pre-existing microcracks, and tooth-related characteristics (such as age and degree of dentin sclerosis).

In this regard, Coli *et al*.[24] also investigated the surface roughness and SBS. In their study, surface preparation was performed using five different substances: 0.2% EDTA, sandblasting with $Al_2O_3$ particles + 0.2% EDTA, 10% $H_3PO_4$, 10% $H_3PO_4$ + collagenase solution (Immersed), and a control group. The investigations were conducted on both cervical and lateral sections of the samples. Interestingly, Coli *et al*.[24] found no significant difference in

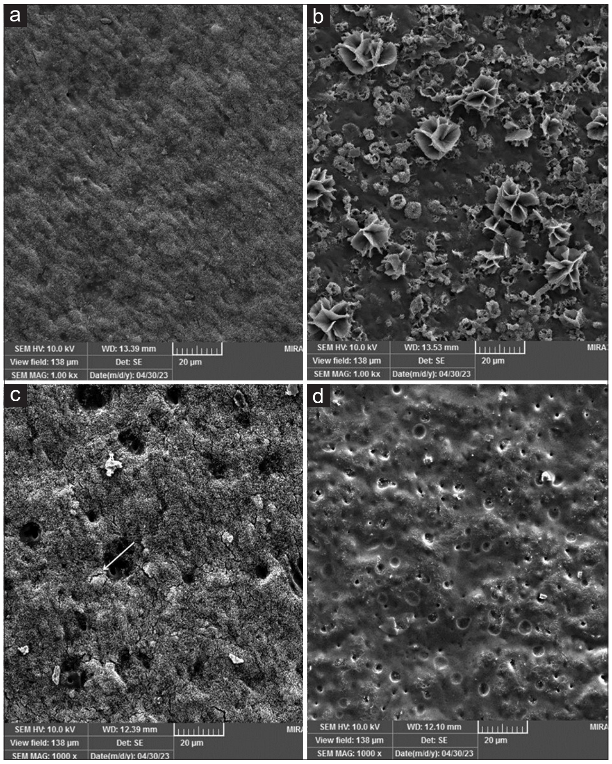


**Figure 8:** SEM image of extra samples (experimental group) from the surface view: (a) sandblasted group from a distance of 5 mm with acid etch preparation; (b) sandblasted group from a distance of 5 mm with acidic primer preparation; (c) sandblasted group from a distance of 10 mm with acid etch preparation, microcracks (white arrow); (d) sandblasted group from a distance of 10 mm with acidic primer preparation

the average SBS between the cervical and lateral sections. The highest average SBS was observed in the 10% $H_3PO_4$ + collagenase solution group, which showed a significant difference when compared to the sandblast group ($P < 0.05$). Surprisingly, there was no significant difference between the control and sandblasted groups. It is important to note that the differences in sandblasting conditions between the two studies make it challenging to make an accurate comparison. Nevertheless, the limited effectiveness of sandblasting was evident in both studies. In the current study, sandblasting was performed at both 5- and 10-mm distances from the tooth surface. Surprisingly, the samples subjected to sandblasting at a distance of 5 mm exhibited lower bond strength compared to those sandblasted at a distance of 10 mm. This may be attributed to several factors. When sandblasting is conducted at a greater distance, there is likely to be better dispersion of particles, resulting in the creation of a more uniform and evenly treated surface. Further, the impact energy of $Al_2O_3$ particles striking the dentin surface may be reduced, resulting in less damage to the dentin structure. As such, fewer particles are left on the surface after sandblasting.

EDX analysis confirmed these observations, as the percentage of $Al_2O_3$ detected at a distance of 5 mm was higher than that at a distance of 10 mm. However, the difference between the two sandblasting distances was not significant. To further explore the effect of sandblast distance on repair bond strength, Burrer *et al*. conducted a study.[25] Interestingly, their findings showed no significant difference between 1-, 5-, 10-, and 15-mm sandblast distances, but both the 10-mm and 15-mm distances were significantly different from the control group. Nevertheless, it is crucial to consider the variations in thermocycling (×5000), sandblasting conditions, and the different substrate used in the present study, which may have contributed to the nonalignment of the results with the study of Burrer *et al*.[25]

In accordance with the findings of the present study, previous research has also demonstrated a decline in bond strength due to sandblasting. For instance, the study conducted by Soares *et al*.[26] examined the effect of sandblasting on the bond strength of two types of self-etch adhesives. Their results revealed that the micro-SBS of the sandblasted group was significantly lower than that of the control group. Similarly, the study by Ouchi *et al*.[21] inspected the impact of sandblasting (using 50-µ particles, 2.5 bar pressure, and 10 mm distance) on the bond strength of various types of self-etch universal adhesives. Interestingly, the authors reported that while sandblasting did not significantly affect the bond of universal adhesives to enamel, it did lead to a reduction in the bond strength to dentin, regardless of the type of universal adhesive used. The SEM findings in the present study, as well as Ouchi *et al*.'s study,[21] indicate an increase in the amount and compression of the smear layer compared to the control group. The smear layer typically contains collagen fragments which may impede the penetration of self-etch functional adhesive monomers and total-etch adhesive resin. Unlike etch-and-rinse adhesives, self-etch adhesives barely penetrate beyond the smear layer and do not create long resin tags.[27,28]

According to Table 3 of the present study, the type of adhesive did not show a significant difference as a between factor (independent variable) ($P = 0.900$). The Distance × Adhesive interaction did not show a significant difference either in the bond strength ($P = 0.889$). These findings suggest that the reduction in bond strength may be attributed to factors other

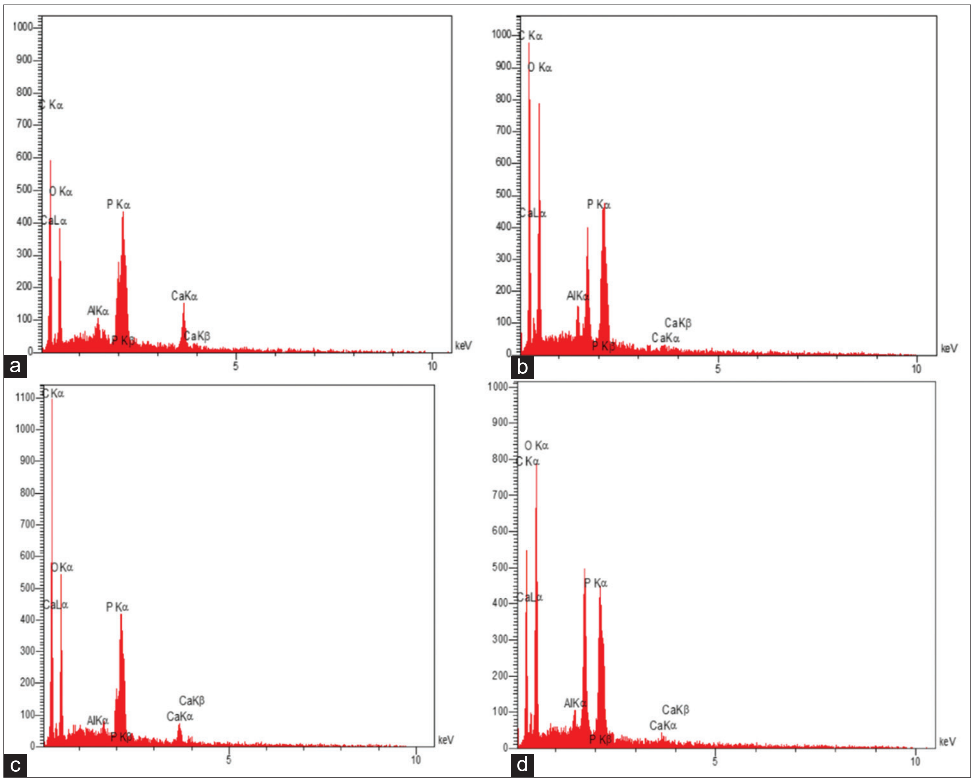


**Figure 9:** EDX diagram of the extra samples (sandblasting groups): (a) self-etch group at 5 mm distance; (b) total-etch group at 5 mm distance; (c); self-etch group at 10 mm distance (d) total-etch group at 10 mm distance

than the adhesive type and distance, such as the effect of sandblasting on the dentin surface and surface contaminating. The design of this study aimed to explore the impact of sandblasting on the bond strength in the gingival floor of Class II cavities in direct restorations, which is an area that has not been extensively studied. It is evident that proper isolation is crucial to control contaminating factors in Class II composite restorations. In the present study, considerable effort was made to ensure adequate isolation under laboratory conditions.

Note that the outcome of the present study might differ under clinical conditions. Thus, future clinical studies may offer valuable insights into the effectiveness of sandblasting as a surface preparation technique in Class II restorations. Such studies can help provide practical guidelines for dental practitioners in achieving optimal bond strength and long-lasting restorations in the challenging gingival floor area. The present study had certain limitations that need to be considered when interpreting the findings. One of the most notable limitations was its laboratory nature, which may not fully reflect the complexity of clinical conditions. Real-world clinical scenarios involve multiple variables that could influence the bond strength, and thus, clinical findings may differ from those observed in the present study.

Another limitation was nonexamination of the thickness of the smear layer, which could have provided additional insights into the interaction between sandblasting and the dentin surface. In addition, the study used only one type of self-etch adhesive due to time and financial constraints. Considering the wide variety of adhesive materials available in clinical practice, investigating the effects of sandblasting on different adhesive systems could provide a more comprehensive understanding of its impact on bond strength.

Furthermore, the study focused on short-term bond strength results, while the long-term durability of the bonding interface after sandblasting remains unknown. Future studies with extended follow-up periods are suggested to evaluate the stability and longevity of the bond in real clinical situations.

Sandblasting, as a surface preparation method aimed at creating a microchannel bond, may not fully address the specific challenges, potentially limiting its efficacy in improving bond strength in the gingival floor of Class II cavities. Investigating the effectiveness of various surface preparation methods in different clinical scenarios can provide valuable information for dental practitioners in selecting the most suitable technique for enhancing bond strength.

## CONCLUSION

The present study explored the effect of sandblasting on the SBS of cervical dentin using $Al_2O_3$ particles of 50 µ size, 2 bar pressure, and 2-s duration. The results revealed that sandblasting led to a reduction in the adhesive resin bond strength of cervical dentin. This decline in the bond strength may be attributed to several factors, including the production of a smear layer, damage to the dentin structure, surface contamination with $Al_2O_3$ particles, and the unique characteristics of cervical dentin. Interestingly, the decrement in the bond strength was more pronounced in the self-etch adhesive group compared to the total-etch adhesive group, but the type of adhesive system had no significant effect on the bond strength. Furthermore, the distance of sandblasting from the dentin surface also influenced the bond strength. Samples that were sandblasted at a closer distance of 5 mm exhibited a lower bond strength compared to those sandblasted at 10 mm. However, this difference in distance did not yield statistically significant results.

Considering the limitations of this *in vitro* study, such as its laboratory nature and the use of a single type of adhesive, caution should be exercised in extrapolating the findings to clinical practice. Based on the study's outcomes, sandblasting before restoring Class II restorations may not be a favorable method for enhancing bond strength properties.

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### Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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