Original Article

The effect of surface treatments of tooth on the shear bond strength of direct composite veneers: An *in vitro* scanning electron microscope study

Tanvi Shah, Sandeep Hima Adimulapu, Nivedhitha MS, Astha Mehta[1], Surendar Sugumaran

Department of Conservative Dentistry and Endodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, [1]Nair Hospital Dental College, Mumbai, Maharashtra, India

Abstract

Background: The bond strength between tooth structure and restorative materials is critical for the long-term success of dental restorations. This study sought to determine how the shear bond strength (SBS) and type of bond breakdown were affected by the inclusion of sandblasting (SB) as a conditioning step before acid etching (AE).

Materials and Methods: A total of 40 extracted human molars were split into two groups at random: intervention (SB followed by AE) and control (AE only). Composite resin cylinders were constructed on the tooth surface following the application of the bonding agent. A universal testing device was used to determine the SBS, and scanning electron microscopy was used to assess the kind of bond failure.

Results: In comparison to the control group, the intervention group displayed a significantly higher SBS ($P < 0.05$). In contrast to the control group, which showed more adhesive failure at the tooth–resin interface, the intervention group also demonstrated a larger percentage of cohesive failure within the composite resin.

Conclusion: As an extra conditioning step, AE after SB considerably increased the SBS between tooth structure and composite resin. The fact that the intervention group experienced a higher percentage of cohesive failure shows that this technique could boost the bond's longevity.

Keywords: Acid etching; bond strength; composite; sandblasting; veneers

INTRODUCTION

Restoring a patient's lost dental esthetic appearance is the primary objective of dentistry in the anterior area. Due to rapid advancements in adhesive dentistry, the range of treatment options has also expanded.[1] The two most commonly available options include direct composite restorations or ceramic laminate veneers.

Not only can direct composite restorations be performed with minimal tooth tissue reduction compared to ceramic veneers, but they also require less chairside time and are cost-friendly.[1] If discolored or malposed teeth require correction, doing so would be cumbersome with ceramic veneers, as the color of the veneer is a combination of the tooth structure, the luting cement, and the veneer, serving as a notorious disadvantage of ceramic veneers.[2] Furthermore, direct composite restorations help achieve natural tooth anatomy easily without laboratory intervention and are under the direct control of the clinician.[2]

In a 2010 study conducted by van Dijken and Pallesen on Class IV direct composite restorations, it was observed

Address for correspondence:
Dr. Sandeep Hima Adimulapu,
Department of Conservative Dentistry and Endodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India.
E-mail: himas.sdc@saveetha.com

Date of submission : 25.05.2023
Review completed : 20.06.2023
Date of acceptance : 06.07.2023
Published : 16.09.2023

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jcde

DOI: 10.4103/jcd.jcd_354_23

How to cite this article: Shah T, Adimulapu SH, Nivedhitha MS, Mehta A, Sugumaran S. The effect of surface treatments of tooth on the shear bond strength of direct composite veneers: An *in vitro* scanning electron microscope study. J Conserv Dent Endod 2023;26:539-43.

that despite drawbacks such as color fading and wear, approximately 36.5% of the restorations had experienced fractures after an average of 8.8 years. In comparison, ceramic veneers had a failure rate of <5% after 5 years, mainly due to retention loss or fractures.[3]

With conventional adhesive systems, direct composite veneers have a 5-year survival rate of 80%–89%.[4,5] Due to relatively significant debonding rates, enamel bonding in direct composite veneers has to be improved.

Conditioning is necessary to guarantee the long-term strength of the link between the composite material and the tooth tissue surface. The three types of surface conditioning procedures are mechanical, chemical, and chemicomechanical, depending on the mechanism of action.[6] Mechanical surface treatment techniques include diamond rotary tools, airborne abrasion, and tooth material reduction. Chemical conditioning would include the use of sodium ascorbate hydrogel after enamel etching. The conventional chemical technique involves etching the tooth surface, followed by the application of a silane coupling agent, disregarding the risks associated with hydrofluoric acid gel. The focus of this work is airborne abrasion and etching of the abraded tooth surface, whereas chemicomechanical would include merging these two approaches. Sandblasting (SB) procedures, meanwhile, are still not given a lot of significance. Results from an earlier investigation by D'Arcangelo and Vanini supported the claim that SB increased the mechanical retention of indirect composite restorations. When compared to the single-etched enamel group, the sandblasted silane group's adhesive failure rate was 10.6%.[4]

Therefore, the goal of this study was to ascertain the difference in bond strength between acid etching (AE) and SB the tooth as an additional tooth conditioning step, followed by scanning electron microscopy (SEM) analysis of the bond failure site. The null hypothesis under test was that there is no difference between the groups in terms of shear bond strength (SBS) or kind of bond failure.

MATERIALS AND METHODS

The study was approved by the Review Board of our institute (SRB/SDC/ENDO-2101/22/071) and follows the Checklist for Reporting *in-vitro* Studies Guidelines.

Specimen preparation

There were 40 newly extracted anterior teeth in total, which were kept in distilled water at 37°C. After being derooted, the teeth were implanted longitudinally in cold-cure acrylic resin, leaving the labial surface exposed for bonding. The surfaces were prepared for direct composite veneers by utilizing 0.3 mm depth cutting diamond points followed by finishing burs to reserve the tooth preparation in the enamel, resulting in a total enamel reduction of 0.5 mm. After that, the teeth were randomly split into two groups of 20 samples each.

Acid etching-only group – Control

After preparing the enamel surface, it was etched for 30 s using 37% orthophosphoric acid gel (Eco-Etch Ivoclar Vivadent), properly washed with water, and gently dried with oil-free air.

The next step involved applying a thin coating of TE-Econom Bond Dental Adhesive (Ivoclar Vivadent), gently blowing it with a jet of oil-free air, and then curing the adhesive for 20 s using a 1200 mW/cm^2 LED-curing light (LED-D Light Cure, Guilin Woodpecker Medical Instrument Co., Ltd., China).

Sandblasting and acid etching group – Intervention

The prepared enamel surface is subjected to a 5 s SB process using 50 µ aluminum oxide at 80 psi and a 10 mm nozzle distance. The surface is next cleansed with oil-free air, followed by the application of an AE solution and a bonding agent, much like in the AE group.

After both groups' surfaces had been treated, the samples were bonded with composite resin (Tetric N-Ceram Bulk Fill, Ivoclar Vivadent, Zurich, Switzerland) using a fixed diameter (4 mm) and height (6 mm) split mold and in increments of 2 mm. The samples were then light-cured for 30 s using a 1200 mW/cm^2 LED-curing light (LED-D Light Cure, Guilin Woodpecker Medical Instrument Co., Ltd., China).

The specimens underwent further thermocycling fatigue tests (5000 cycles, dwell times of 30 s, temperatures ranging from 5°C to 550°C). The SBS was evaluated following a further 24 h of distilled water storage at room temperature. By labeling the samples with various colors that were only known to the operators, the investigators were rendered blind.

A universal testing machine (Instron E300 Universal Testing Machine) was used to conduct the test till fracture at a crosshead speed of 1 mm/min. After conducting a statistical analysis, the peak load was divided by the bonding area to get the load at fracture in MPa.

To determine the kind of bond failure, the teeth were examined under a stereomicroscope (brand) at a ×20 magnification. The adhesive remnant index (ARI),[7] which has been updated to incorporate an enamel fracture score (EF), was used to measure the remaining adhesive on the teeth.[8] Where "Score 0" meant "No adhesive remained on enamel," "Score 1" meant "<50% of the adhesive remained on enamel," "Score 2" meant "More than 50% of the adhesive remained on enamel," "Score 3" meant "All adhesive remained on enamel," and "EF" meant "Enamel Fracture."

The ARI scores were also applied as a more sophisticated approach of identifying the enamel, adhesive, and resin bond failure location [Figure 1].

SEM analysis was conducted on the teeth to assess the nature of bond failure.

Scanning electron microscopy

Two representative samples for each group were then subjected to SEM (FE-SEM IT800, 0–30KV, Jeol, USA. Inc.). The samples were mounted on SEM studs with carbon tape for stabilization, followed by platinum sputter coating. They were observed under ×20 magnification, 1.00 kV as seen in Figure 2.

Statistical analysis

Descriptive statistics, including the mean and standard deviation, were calculated for each group using a statistical software package (IBM Corporation, released 2021); IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY, USA: IBM Corporation. The bond strength data were analyzed by conducting the Kolmogorov–Smirnov normality test and the Levene variance homogeneity test. An independent sample *t*-test was applied for bond strength data and Pearson's Chi-square test for the ARI score. The level of significance was set at $P < 0.05$.

RESULTS

The findings demonstrated that the SBS values between the various tooth surface treatments varied significantly [Table 1]. SBS between buccal enamel and resin was considerably increased by SB before bonding.

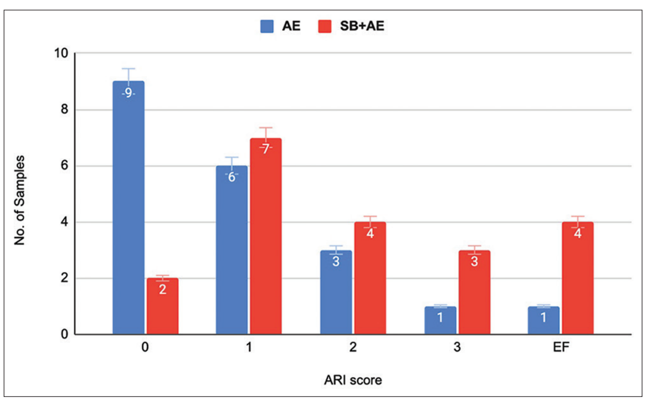

Figure 1: Grouped bar graph depicting adhesive remnant index scores for (acid etch [AE] group) and (sandblasting + AE group). X-axis shows scores 0–3 and enamel fracture (EF), Y-axis shows frequency of the scores corresponding to the groups. Score 0 indicates major adhesive failure, EF indicates cohesive failure, and scores 1–3 indicate mixed failure. ARI: Adhesive remnant index, AE: Acid etching, SB: Sandblasting, EF: Enamel fracture

The enamel/composite interface of the intact enamel specimens exhibited primarily adhesive bond failure, whereas the sandblasted specimens exhibited cohesive bond failure with a higher frequency of EF. Pure adhesive failure was present in 45% of the AE group, cohesive failure was present in 20% of the SBAE group, and mixed failure was present in 50% and 70% of the AE and SBAE groups, respectively [Table 2].

Table 1: Group statistical data with mean and standard deviation of bond strength tested for etching only and sandblasted + etching groups

SBS data				
Groups	Sample size	Mean (MPa)	SD	*P*
AE	20	13.34	0.94	<0.001
SB + AE	20	19.57	1.77	
Total	40			

The scores show a statistically significant increase in shear bond strength when SB is done as an additional step, SD: Standard deviation, AE: Acid etching, SB: Sandblasting, SBS: Shear bond strength

Table 2: Mode of failure of bond between acid etching group and sandblasting + acid etching groups in percentages adhesive remnant index Score 0 is considered "Adhesive Failure", Score enamel fracture is considered "Cohesive Failure," and scores 1–3 are considered "Mixed Failure"

Type of failure	AE (%)	SB + AE (%)
Adhesive	45	10
Cohesive	5	20
Mixed	50	70

AE: Acid etching, SB: Sandblasting

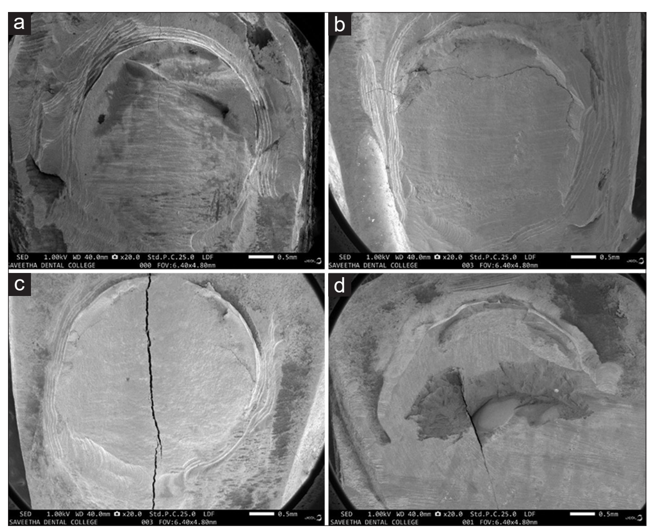

Figure 2: Scanning electron microscopy (SEM) images of samples to analyze bond failure. (a and b) show SEM images of the (acid etch) AE group after testing showing scores of 0 and 1, respectively, (c and d) showing SEM images of the (sandblasting + acid etch) SB+AE group after testing with Score 1 and 2 with enamel fracture

Prior to bonding, SB shifted the failure point from the composite interface to the enamel interface. The bond failure location was moved away from the enamel/composite contact by SB. SB, thereby, improved resin adherence to the enamel.

DISCUSSION

This study aimed to assess the impact of different surface conditioning methods on the SBS and type of bond failure of veneers placed on prepared enamel surfaces. SEM analysis was conducted to evaluate the bond failure site. The findings indicated a statistically significant difference in SBS and ARI scores among the groups. Thus, the null hypothesis stating that there is no difference in SBS and type of bond failure among the groups was rejected.

The enamel surface of teeth is primarily made up of highly mineralized hydroxyapatite crystals that provide them with their strength and durability. In order for a material to bond with enamel, it must possess properties that can counter the enamel's strong mineral structure and establish a robust bond.[5]

Adhesion with enamel surface is affected by several factors, such as the material's chemical composition, the enamel's surface characteristics, and the bonding mechanism employed. One common bonding technique is AE, which creates a micromechanically retentive structure on enamel by selectively dissolving its inorganic structure. This allows monomers to penetrate and form resin tags in the enamel.[1] In the present study, the AE group had comparatively poor scores for SBS when compared to SB and etching group.

The unique surface characteristics achieved through AE of uncut enamel surfaces for bonding can be attributed to the presence of prismless enamel. This specific type of enamel is responsible for creating the complex profile observed after etching, contributing to the enhanced bonding effect.[9] This particular substrate consists of areas with apatite crystals arranged in a parallel and densely packed manner, which provides it with high resistance against acid erosion.[10] When AE is applied to cut enamel surfaces, it selectively dissolves the carbonate-rich core of vertically oriented enamel prisms, leading to the formation of protrusions at the boundaries between prisms (known as type I etching). This phenomenon has been observed and documented in previous scanning electron microscope studies.[9,11] Furthermore, the low average roughness values of specimens subjected to AE may be due to its lesser effect on organic materials compared to that of SB.

The SEM study for bond failure with ARI scores showed that the AE group experienced more adhesive failure, while the SBAE group experienced more cohesive failure. The acid used to cure enamel dissolves the ends of the enamel rods in the remaining enamel while removing around 10 μm of enamel from the surface. The outcome is the formation of 25–75 m-deep porosities, which act as a network of channels into which an unfilled resin or resin bonding agent can flow, expanding the surface area by more than 2000 times. The mechanical connection between the tooth and resin is significantly strengthened by these alterations. 85% phosphoric acid was utilised by Bunocore. The deepest channels in permanent enamel are produced by etching with 20%–50% phosphoric acid, according to later investigations. Finally, according to studies, the appropriate concentration of phosphoric acid is 37%.[12,13]

Professionals in dental hygiene[14] originally mentioned using alumina particles for intraoral SB in 1945. With the use of this approach, the adhesive strength of brackets attached to restorative materials such as amalgam, metals, composites, and ceramics is increased, while the surface area is increased.[15,16] The literature discusses whether SB on an enamel surface before or in place of etching will improve bonding qualities, but the relevant studies come up short. Some authors assert that SB before etching does not improve bonding strength.[10,17] Others, however, found no statistically significant improvement in relationship strength despite a propensity.[18,19] Others, despite a predisposition, found no statistically significant gain in bonding strength.[20,21] However, some of them questioned the applicability of their discoveries.[22,23]

The rough enamel surface achieved through a combination of SB and AE is representative of type I etching. This technique results in maximal enamel loss, free from any interference caused by alumina particles, and enables superior resin infiltration that is both extensive and of higher quality compared to AE alone.[24] In addition, SB can clear away any impurities or debris from the enamel's surface, enabling the etchant and adhesive to adhere to the enamel more effectively. This makes sure that the etchant and adhesive can work together to connect strongly with the enamel surface.

Intraoral SB, while an effective method for improving bond strength, does have a limitation in that it poses potential safety hazards to both the patient and the operator. The use of abrasive particles during the SB process creates a cloud of dust and debris, which can be harmful if inhaled by either party.

Therefore, to minimize the risks associated with SB, it is necessary to use rubber dam isolation to isolate the tooth being treated and high vacuum suction to remove any particles generated during the process. In addition, safety eyewear must be worn to protect the eyes from any flying debris.

While these safety measures are important to ensure the health and safety of both the patient and the operator, they do add time and complexity to the treatment procedure, which may be a limitation in a busy clinical setting where time is a valuable resource. Nonetheless, the use of proper safety measures during intraoral SB is crucial to preventing potential harm to both the patient and the operator.

The micro-SBS (μ-SBS) test has recently been promoted as a modified approach for determining how well dentin-adhesive systems can adhere.[25] The μ-SBS test is superior to the μ-SBS test because it uses smaller specimens, which results in fewer internal flaws and more uniform stress distributions at the interface.[26-29]

CONCLUSION

This study found significant differences in SBS and ARI scores between enamel surface conditioning methods. While AE is a conventional technique, it produced poorer scores compared to SB and etching. Intraoral SB with alumina particles was found to create a rough enamel surface, allowing for better penetration of the etchant and adhesive, resulting in improved bond strength. However, SB does pose potential safety hazards and requires proper safety measures. Therefore, clinicians should consider the benefits and limitations of each method when deciding on the appropriate enamel surface conditioning technique.

Acknowledgments

We acknowledge the valuable contributions of all individuals and institutions that have supported and contributed to this research manuscript.

Our sincere gratitude goes to our institution, supervisor, participants, and colleagues for their invaluable support and assistance.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Gresnigt MM, Sugii MM, Johanns KB, van der Made SA. Comparison of conventional ceramic laminate veneers, partial laminate veneers and direct composite resin restorations in fracture strength after aging. J Mech Behav Biomed Mater 2021;114:104172.
2. Christensen GJ. Restoring a single anterior tooth: Solutions to a dental dilemma. J Am Dent Assoc 2004;135:1725-7.
3. van Dijken JW, Pallesen U. Fracture frequency and longevity of fractured resin composite, polyacid-modified resin composite, and resin-modified glass ionomer cement class IV restorations: An up to 14 years of follow-up. Clin Oral Investig 2010;14:217-22.
4. D'Arcangelo C, Vanini L. Effect of three surface treatments on the adhesive properties of indirect composite restorations. J Adhes Dent 2007;9:319-26.
5. Lacruz RS, Habelitz S, Wright JT, Paine ML. Dental enamel formation and implications for oral health and disease. Physiol Rev 2017;97:939-93.
6. Bajraktarova-Valjakova E, Grozdanov A, Guguvcevski L, Korunoska-Stevkovska V, Kapusevska B, Gigovski N, *et al.* Acid etching as surface treatment method for luting of glass-ceramic restorations, part 1: Acids, application protocol and etching effectiveness. Open Access Maced J Med Sci 2018;6:568-73.
7. Behnaz M, Dalaie K, Mirmohammadsadeghi H, Salehi H, Rakhshan V, Aslani F. Shear bond strength and adhesive remnant index of orthodontic brackets bonded to enamel using adhesive systems mixed with TiO2 nanoparticles. Dental Press J Orthod 2018;23:43.e1-7.
8. Lalani N, Foley TF, Voth R, Banting D, Mamandras A. Polymerization with the argon laser: Curing time and shear bond strength. Angle Orthod 2000;70:28-33.
9. Lehman R, Davidson CL. Loss of surface enamel after acid etching procedures and its relation to fluoride content. Am J Orthod 1981;80:73-82.
10. Brauchli L, Muscillo T, Steineck M, Wichelhaus A. Influence of enamel conditioning on the shear bond strength of different adhesives. J Orofac Orthop 2010;71:411-20.
11. Türköz C, Ulusoy C. Evaluation of different enamel conditioning techniques for orthodontic bonding. Korean J Orthod 2012;42:32-8.
12. Gourav R, Ariga P, Jain AR, Philip JM. Effect of four different surface treatments on shear bond strength of three porcelain repair systems: An *in vitro* study. J Conserv Dent 2013;16:208-12.
13. Moezizadeh M, Ansari ZJ, Fard FM. Effect of surface treatment on micro shear bond strength of two indirect composites. J Conserv Dent 2012;15:228-32.
14. Wiechmann D. Lingual orthodontics (Part 3): Intraoral sandblasting and indirect bonding. J Orofac Orthop 2000;61:280-91.
15. Neugebauer S, Jost-Brinkmann PG, Pätzold B, Cacciafesta V. Plasma versus halogen light: The effect of different light sources on the shear bond strength of brackets. J Orofac Orthop 2004;65:223-36.
16. Sperber RL, Watson PA, Rossouw PE, Sectakof PA. Adhesion of bonded orthodontic attachments to dental amalgam: *In vitro* study. Am J Orthod Dentofacial Orthop 1999;116:506-13.
17. Robles-Ruíz JJ, Ciamponi AL, Medeiros IS, Kanashiro LK. Effect of lingual enamel sandblasting with aluminum oxide of different particle sizes in combination with phosphoric acid etching on indirect bonding of lingual brackets. Angle Orthod 2014;84:1068-73.
18. Pakshir HR, Zarif Najafi H, Hajipour S. Effect of enamel surface treatment on the bond strength of metallic brackets in rebonding process. Eur J Orthod 2012;34:773-7.
19. Reisner KR, Levitt HL, Mante F. Enamel preparation for orthodontic bonding: A comparison between the use of a sandblaster and current techniques. Am J Orthod Dentofacial Orthop 1997;111:366-73.
20. Suma S, Anita G, Chandra Shekar BR, Kallury A. The effect of air abrasion on the retention of metallic brackets bonded to fluorosed enamel surface. Indian J Dent Res 2012;23:230-5.
21. Mati M, Amm E, Bouserhal J, Bassil-Nassif N. Effects of buccal and lingual enamel sandblasting on shear bond strength of orthodontic brackets bonded with a self-etching primer. Int Orthod 2012;10:422-31.
22. Cal-Neto JP, Castro S, Moura PM, Ribeiro D, Miguel JA. Influence of enamel sandblasting prior to etching on shear bond strength of indirectly bonded lingual appliances. Angle Orthod 2011;81:149-52.
23. Miles PG. Does microetching enamel reduce bracket failure when indirect bonding mandibular posterior teeth? Aust Orthod J 2008;24:1-4.
24. Patcas R, Zinelis S, Eliades G, Eliades T. Surface and interfacial analysis of sandblasted and acid-etched enamel for bonding orthodontic adhesives. Am J Orthod Dentofacial Orthop 2015;147:S64-75.
25. Eren D, Bektaş ÖÖ, Siso SH. Three different adhesive systems; three different bond strength test methods. Acta Odontol Scand 2013;71:978-83.
26. Braga RR, Meira JB, Boaro LC, Xavier TA. Adhesion to tooth structure: A critical review of "macro" test methods. Dent Mater 2010;26:e38-49.
27. Dabas D, Patil AC, Uppin VM. Evaluation of the effect of concentration and duration of application of sodium ascorbate hydrogel on the bond strength of composite resin to bleached enamel. J Conserv Dent 2011;14:356-60.
28. Abd Wahab MH, Bakar WZ, Husein A. Different surface preparation techniques of porcelain repaired with composite resin and fracture resistance. J Conserv Dent 2011;14:387-90.
29. Petrauskas A, Novaes Olivieri KA, Pupo YM, Berger G, Gonçalves Betiol EÁ. Influence of different resin cements and surface treatments on microshear bond strength of zirconia-based ceramics. J Conserv Dent 2018;21:198-204.