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Original Article

Evaluation of shear bond strength of labial veneers after sandblasting/micro-abrasion of prepared teeth by aluminum oxide particles. An in-vitro study

Abdullah Alayad [a,*], Ahmed Alduraywishi [b], Nawaf Alhatarisha [b], Yousef Khalaf [b], Ahmed Alobaid [b], Muath Aldosari [c]

[a] Department of Restorative Dentistry, Operative Division, College of Dentistry, King Saud University, Riyadh, Saudi Arabia
[b] College of Dentistry, King Saud University, Riyadh, Saudi Arabia
[c] Department of Periodontology and Community Dentistry, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

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ABSTRACT

Objectives: To explore the feasibility and effectiveness of using sandblasting with aluminum oxide particles to improve the shear bond strength of labial veneer restorations in dentistry.

Materials and Methods: A sample size of 50 extracted teeth was divided into five groups, with each group containing ten teeth (n = 10) subject to different treatment protocols. Group 1the control group, underwent conventional surface treatment for labial veneer restorations, including the application of phosphoric acid etchant and bonding protocols. Groups 2 and 3 underwent micro-abrasion using aluminum oxide particles alone for durations of 30 and 45 s, respectively. Groups 4 and 5 experienced a combined approach of micro-abrasion for 30 and 45 s, respectively, followed by conventional surface treatment. The shear bond strength test was performed on each specimen. The resulting modes of failure and surface characteristics were then examined under a digital microscope.The data was analyzed statistically using a one-way analysis of variance (ANOVA) and a post hoc test.

Results: Significant differences were observed in shear bond strength among the five groups ($p < 0.05$). The group that underwent conventional + 45-second micro-abrasion treatment exhibited the highest mean shear bond strength (25.69 MPa), while the conventional (controlled) group had the lowest (9.01 MPa).

Conclusion: Fusing sandblasting and aluminum oxide particles could improve the bond strength of labial veneer restorations. Yet, more research is needed to refine this technique for practical application. This includes a broad array of cement types, particle sizes, and clinical situations to ensure the long-term success of veneer restorations.

1. Introduction

Sandblasting is a method employed to boost the effectiveness and longevity of dental restorations such as veneers and crowns. The technique enhances the bond between the tooth surface, the bonding agent, and the restoration material, thus increasing the bond strength (Pini et al., 2015). The type of sandblasting materials and methods used may vary depending on the restoration type and tooth surface condition (Nishigawa et al., 2016). The technique can also fortify the bond between ceramic and composite materials during the repair of damaged restorations (Gresnigt et al., 2021). Further, sandblasting can increase bond strength between orthodontic brackets and enamel surfaces. Its popularity in dentistry has grown in recent years due to its ability to increase bonding strength and improve treatment results, especially in preparing restorative materials and orthodontic brackets (Duzyol et al., 2016). However, it is crucial to choose the right sandblasting particle size, pressure, and duration for optimal results. Clinicians need to avoid excessive tooth preparation to prevent damaging the overall tooth structure and function (Alothman et al., 2018). Employing sandblasting and other conservative techniques can help dental professionals attain visually appealing, durable restorations with minimal damage to natural teeth (Tekçe et al., 2019).

The current literature does not discuss the use of aluminum oxide particles for sandblasting or micro-abrasion on prepared tooth surfaces

* Corresponding author.
E-mail addresses: dr.alayad@gmail.com (A. Alayad), muath_aldosari@hsdm.harvard.edu (M. Aldosari).

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to enhance the bonding strength of labial veneers. This study aimed to investigate the effectiveness of sandblasting on the enamel surface of prepared teeth to increase the bonding strength of labial veneers and to examine the surface characteristics of teeth following a shear bond strength test. The study's null hypothesis is that sandblasting with aluminum oxide particles applied directly to a prepared tooth surface will not affect the shear bond strength of labial veneer restorations.

2. Materials and Methods

The study received ethical approval from the College of Dentistry Research Center's (CDRC) ethics committee at King Saud University (Registration No. #IR 0437) under the IRB Research Project No. (E-22–7187). We conducted in vitro lab trials, which the committee approved, stating no ethical conflicts as there were no human or actual patient trials involved. All tests were performed in a controlled environment by a single clinical investigator to avoid bias.

2.1. Tooth collection

Fifty teeth were extracted for periodontal reasons (Grade III mobility). These specimens underwent thermo-cycling and were randomly divided into five groups. Each group consisted of ten teeth (n = 10/group) and was subjected to various materials and procedures (Table 1).

The usual surface treatment for labial veneer restoration includes applying a 37 % phosphoric acid etchant (DIAETCH) to prepared teeth for 15 s, followed by rinsing and drying. A bonding agent (Go Easy Etchbond Mono) is then applied to all groups for 15 s, and the light is cured for 20 s with a curing pen (E 3 LEDs Curing Light) after material exposure. A 10 % hydrofluoric acid etchant (Maquira Ácido Gel 10 %) is applied to all veneer restorations for 60 s and rinsed. A silane coupling agent is then applied to all restorations. Sandblasting procedures employ the Prophy-Jet (Apollo Prophy-Jet I Codent Europe) with 100 µm aluminum oxide particles. The Prophy-Jet tip is placed around 10 mm from the tooth structure during application. For consistent results, upper central incisors and upper canines, which have long and strong roots, were chosen. Teeth with caries, calculus deposits, severe discoloration, heavy fluorosis, fractures, or craze lines were excluded from the selection.

Table 1
Types of procedures subjected to the samples for all groups with variation in time.

Group Number	Group name	Materials subjected to the group
1	Conventional (controlled)	Ten teeth were prepared and subjected to conventional surface treatment of labial veneer restoration.
2	Micro-abrasion 30 s	Ten teeth were prepared and subjected to micro-abrasion with aluminum oxide particles for 30 s alone.
3	Micro-abrasion 45 s	Ten teeth were prepared and subjected to micro-abrasion with aluminum oxide particles for 45 s alone.
4	Conventional + micro-abrasion 30 s	Ten teeth were prepared and subjected to micro-abrasion with aluminum oxide particles for 30 s in addition to the conventional surface treatment of the labial veneer.
5	Conventional + micro-abrasion 45 s	Ten teeth were prepared and subjected to micro-abrasion with aluminum oxide particles for 45 s in addition to the conventional surface treatment of labial veneer.

2.2. Teeth preparation

To facilitate handling during preparation, teeth were initially embedded in acrylic resin blocks. All groups underwent butt joint preparation for labial veneer restoration, illustrated in Fig. 1, using an upper-canine sample. Our goal was minimal enamel preparation with a chamfer finish line, as teeth are generally better bonded to enamel than dentin. Such a method ensures no significant differences in the results of the shear bond strength of labial veneer restorations. Tooth preparation was completed using depth cutter diamond burs and straight fissure diamond burs for labial veneer restoration. For a clean and smooth outcome, instead of a rough surface, we sequentially used medium and fine Sof-Lex sufflex discs with a diameter of 9.5 mm for finishing.

2.3. Restoration fabrication and cementation

An E-max type veneer restoration was created for all teeth using a CORiTEC 250i Loader PRO cad-cam system. The veneer thickness was 1.5 mm and was fabricated without incisal coverage for every tooth, allowing the shear bond strength tool, known as the knife edge, to fit perfectly at the intersection of the tooth structure and the restoration surface. The restoration design is illustrated in Fig. 2.

Teeth were etched with a 37 % phosphoric acid etchant (DIAETCH) for 15 s before being rinsed and dried. A dual-cured bonding agent (Go Easy Etchbond Mono) was applied to all teeth, air-dried gently, and then light-cured for 15 s with a Curing Pen – E 3 LEDs Curing Light. Following the manufacturer's instructions, 10 % hydrofluoric acid (Maquira Ácido Gel 10 %) was applied to all restorations for 60 s, then rinsed with water.

Cementation of the teeth was carried out using 3 M ESPE RelyX™ Veneer cement and light-cured for 60 s with the Curing Pen. Fig. 2 also presents a sample from each group after the cementation procedure. After cementation, all teeth were finally embedded to facilitate the application of the knife edge for the shear bond strength test.

The shear bond strength test was conducted using a universal testing machine (Instron® 5960, MA, USA). Each sample was tested at a crosshead speed of 1 mm/min, with the maximum load recorded in kN. The machine's knife edge was applied perpendicular to the interface of the tooth structure and labial veneer restoration (Fig. 3). Fig. 4 presents the samples after the completion of the shear bond strength test (see Figs. 5–9).

2.4. Type of failure mode and surface characteristics

The broken samples were analyzed under a microscope (Jeol, Musashino, Akishima, Tokyo, Japan) to evaluate the mode of failure and surface traits. There are three types of failure modes: (1) adhesive failure between the tooth surface and bonding agent, (2) cohesive failure within the cement or restoration surface, and (3) a combination of adhesive and cohesive failure.

As outlined in Table 2, the control group had four samples with adhesive failure and six samples with a combination of failures. The group subjected to micro-abrasion for 30 s had three samples with adhesive failure, 2 samples with cohesive failure, and five samples with a combination of both. The micro-abrasion 45-second group had two samples with adhesive failure, four samples with cohesive failure, and four samples with a combination of the two. The group was treated conventionally and then subjected to micro-abrasion for 30 s. There was one sample with adhesive failure, five samples with cohesive failure, and four samples with a combination. Lastly, the group treated conventionally and then subject to micro-abrasion for 45 s had one, seven, and two samples with adhesive, cohesive, and combination failures, respectively.

2.5. Data analysis

The shear bond strength between labial veneer restorations and

Fig. 1. The butt joint preparation design. On the left is the drawing, and on the right is the actual preparation of one sample from this study.

tooth structure was calculated for all five groups, including standard deviations and means. The data were analyzed using a one-way ANOVA and a 5 % post hoc Tukey's test for multiple comparisons between groups using SPSS (Ver. 22.0, SPSS, Chicago, IL, USA). The significance level was established at $p < 0.05$.

3. Results and statistical analysis

A one-way ANOVA test was utilized to compare the means between groups. A post hoc test provided information on the significantly different means. The null hypothesis asserted that sandblasting tooth surfaces with aluminum oxide particles would not alter the shear bond strength of labial veneer restorations; in other words, the shear pulse speed (SPS) measured in mega-pascals (MPa) across all groups should remain consistent (H_o: $\mu_1 = \mu_2 = \ldots = \mu K$). Conversely, the alternative hypothesis claimed that at least two groups would exhibit different means of shear bond strength. We established the level of significance at $\alpha = 0.05$, with a 95 % confidence interval, degrees of freedom for the numerator (df_1) at 4, and for the denominator (df_2) at 45. We set the critical value at 3.74, thereby rejecting the null hypothesis if this study's F-value exceeded 3.74 or accepting it if the F-value was less than 3.74. Table 3 presents the means, medians, and standard deviations for each group. The conventional (controlled) group yielded the lowest shear bond strength value, at 7.23582 MPa, while the conventional + micro-abrasion 45-second group exhibited the highest at 28.15911 MPa. The SBS means for groups 1 to 5 were successively 9.008265 MPa, 13.486989 MPa, 17.926753 MPa, 21.508807 MPa, and 25.694461 MPa.

The shear bond strength varied amongst all groups, exhibiting significant differences according to the ANOVA test ($p = 0.000$), with an F-value of 140.312, which exceeds the critical value of 3.74. This signifies statistically significant differences in shear bond strength among the five groups tested.

The groups all show statistically significant differences compared to the conventional (control) group, as indicated by a significance level of less than 0.05. Utilizing the Post Hoc Tukey honestly significant difference test to compare shear bond strength across the five tested groups, the micro-abrasion 30-second group exhibited the smallest statistically significant difference from the conventional group, with the lowest mean difference of 4.47 at a significance level of 0.000. The micro-abrasion 45-second group demonstrated a statistically significant difference from the control group, with a mean difference of 8.91 at a significance level of 0.000. The conventional plus micro-abrasion 30-second group also showed a significant difference from the control group, with a mean difference of 12.5 at a significance level of 0.000. Finally, the conventional plus micro-abrasion 45-second group yielded the most substantial statistical difference compared to Group 1, with the highest mean difference of 16.68 and a significance level of 0.000. Fig. 10 illustrates the distribution of group means.

4. Discussion

The esthetic zone refers to the teeth and oral structures visible when smiling. Issues within this zone can negatively impact a person's psychology, leading to diminished confidence and self-esteem. There are various treatment methods available to address these problems, one example being labial veneers. Direct composite restorations are more conservative than labial veneers in terms of preparation design. They can be accomplished in a single visit and are affordable for most dental patients. However, they possess certain drawbacks, including low wear resistance and decreased color stability. Labial veneers were developed to counter these disadvantages and have demonstrated a high survival rate of 98.8 % after 6 years, compared to 36.5 % after 8 years for direct

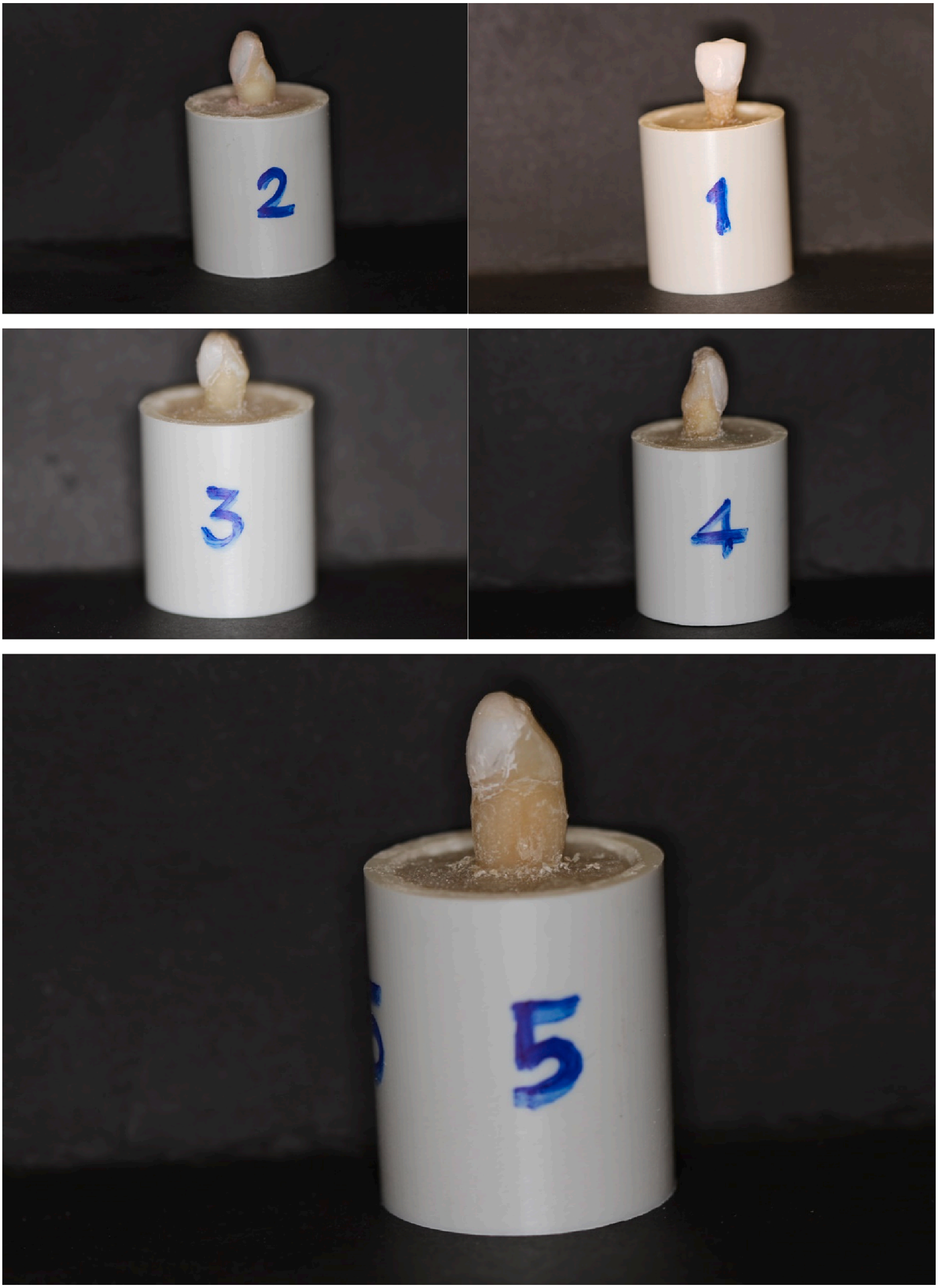

Fig. 2. One tooth from each group after the cementation procedure.

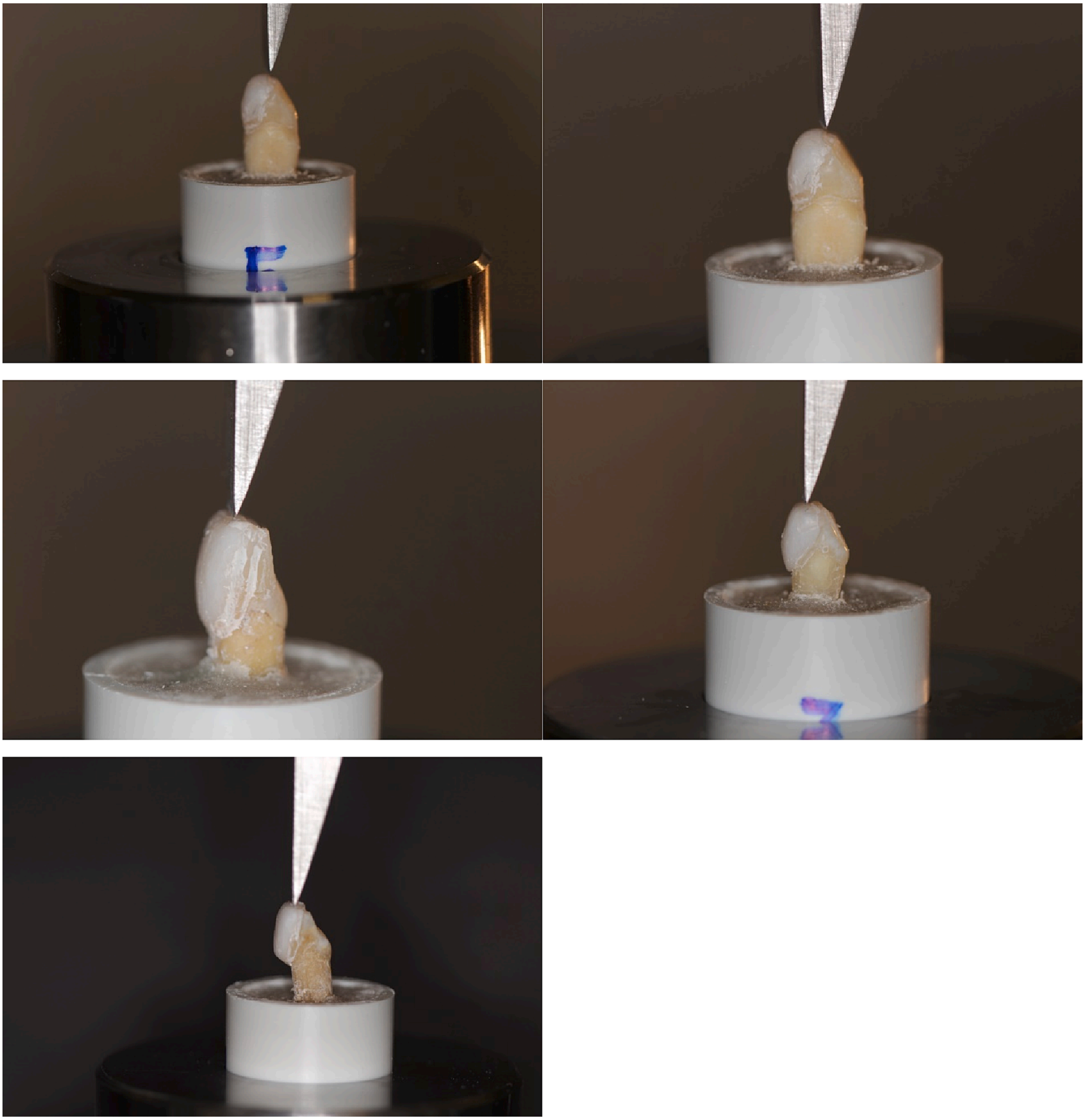

Fig. 3. The knife edge position at the interface of tooth structure and veneer restoration. **A)** one sample from group 5, **B)** one sample from Group 1, **C)** one sample from Group 2, **D)** 1 sample from Group 3, **E)** one sample from Group 4.

composite restorations (Gresnigt et al., 2021).

The goal of laminate veneers is to achieve durable, aesthetic outcomes that satisfy both dentists and patients. This depends on the preparation design and the type of material used to cement the restorations. There are four categories of teeth preparation for veneer restorations: (1) window preparation, characterized by the preservation of the incisal edge of the teeth; (2) feather preparation, characterized by bucco-palatal preparation of the incisal edge of the tooth without reducing the incisal length; (3) bevel preparation, characterized by bucco-palatal preparation of the incisal edge of the tooth with a slight reduction of 0.5 to 1 mm; and (4) incisal overlap preparation, characterized by bucco-palatal preparation of the incisal edge of the tooth with a reduction of about 2 mm, allowing the veneer to extend palatally.

Each preparation design has its own indications that should be applied depending on the clinical situation of the tooth (Alothman et al., 2018). It is essential to preserve the enamel during tooth preparation, as minimal enamel reduction can increase the shear bond strength of the ceramic laminate veneer restoration. However, the clinical situation may require more enamel reduction to achieve a better aesthetic outcome. Minimum preparation of the dentin is acceptable, while extensive dentin preparation should be avoided (Zhu et al., 2022). There is no difference in tensile bond strength between normal and fluorosed enamel; thus, there is no need for a special preparation design for fluorosed enamel (Ratnaweera et al., 2009).

The success of porcelain veneers is largely determined by the strength and durability of the bond formed among three components of the veneer bonding complex: the tooth surface, the luting agent, and the porcelain veneer itself. The presence of residual temporary cement can

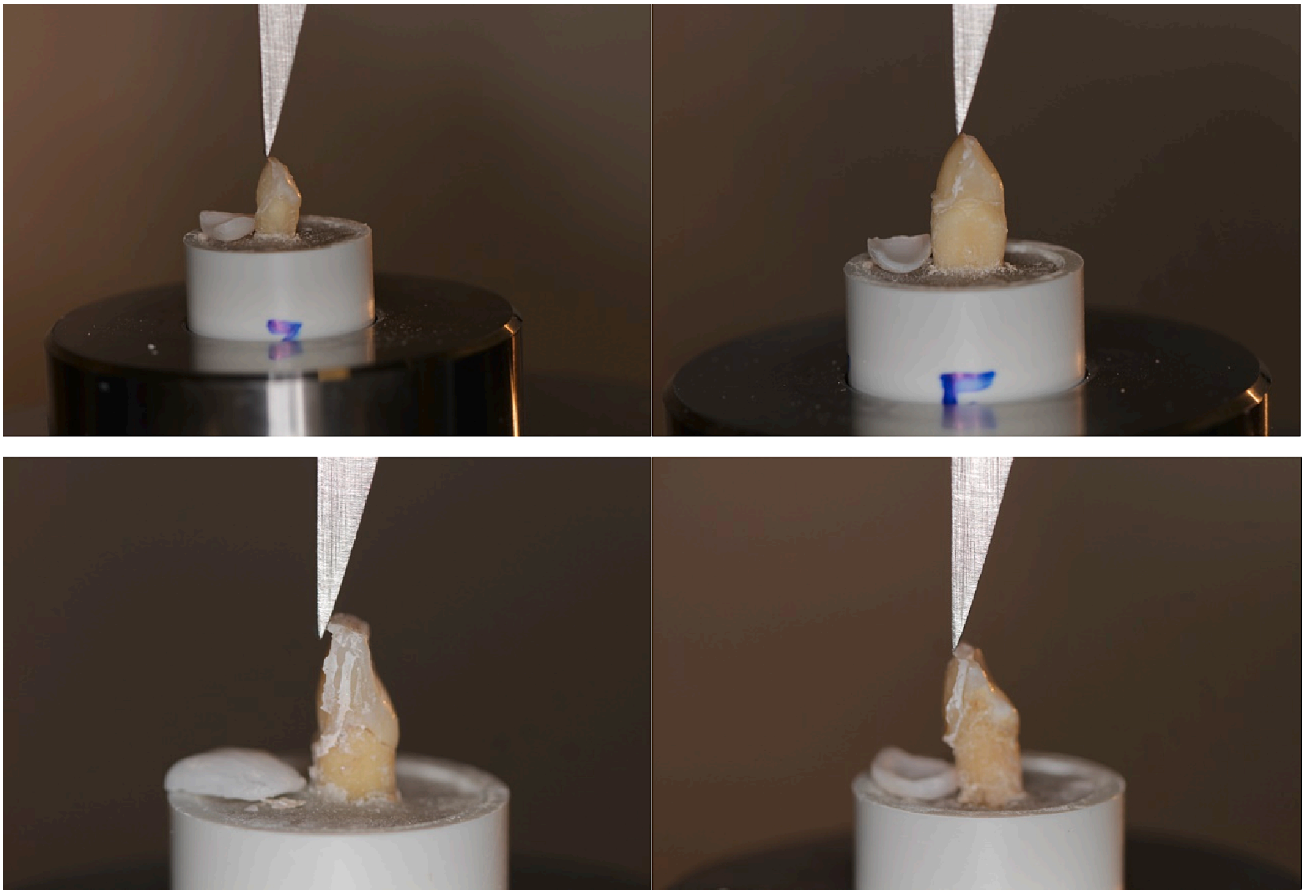

Fig. 4. Failure of restoration after running of SBS testing machine. **A)** One sample from Group 3, **B)** One sample from Group 5**C)** One sample from Group 2, **D)** One sample from Group 4.

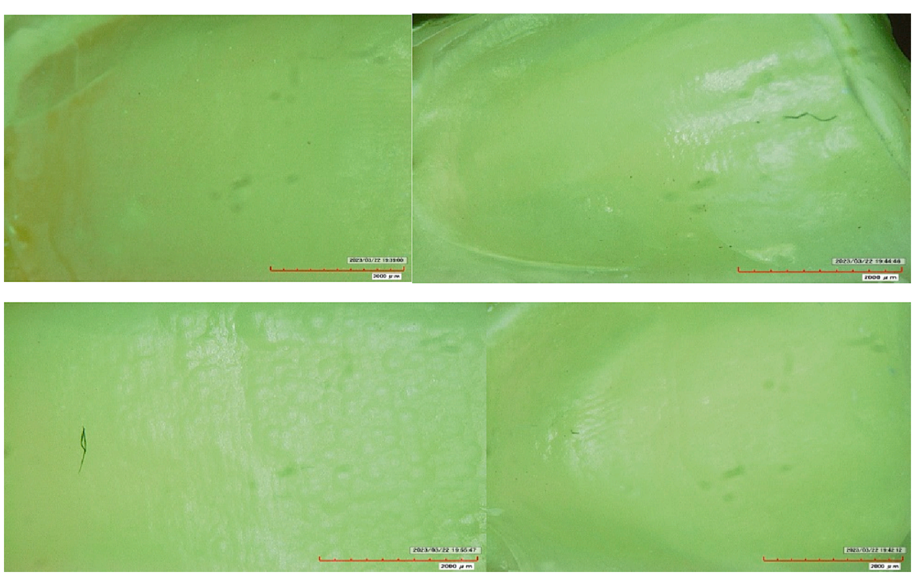

Fig. 5. The surface characteristics under digital microscope for four samples from the conventional (controlled) group.

significantly impact the bond strength of the final veneer restoration. A greater amount of residual and remnants of temporary cement will weaken the bond strength of the final restoration (Kumar et al., 2014). The bonding strength of veneers on enamel is higher than on dentin (Öztürk et al., 2013). However, various techniques have been used to enhance the bond strength of labial veneers, one of which is the abrasion or sandblasting of the restorations.

Micro-abrasion, which involves the use of abrasive substances like pumice and hydrochloric acid, is viewed as a conservative method for treating enamel demineralization defects and tooth discoloration (Pini et al., 2015). To boost outcomes and patient satisfaction, some dentists integrate micro-abrasion with other techniques (Celik et al., 2013).

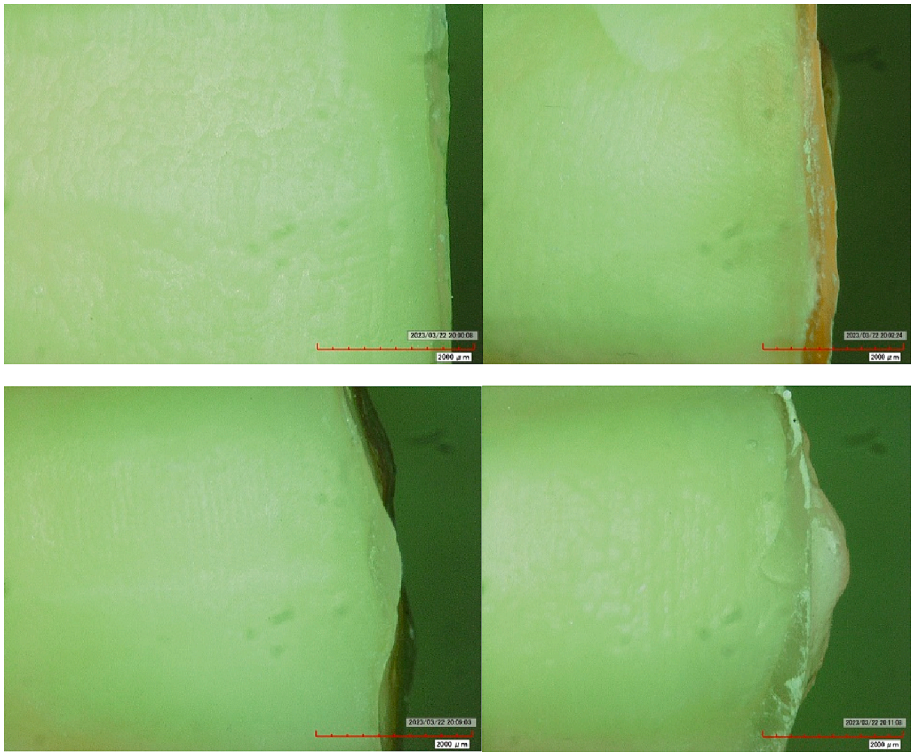

Fig. 6. The surface characteristics under a digital microscope for four samples from the micro-abrasion 30-second group.

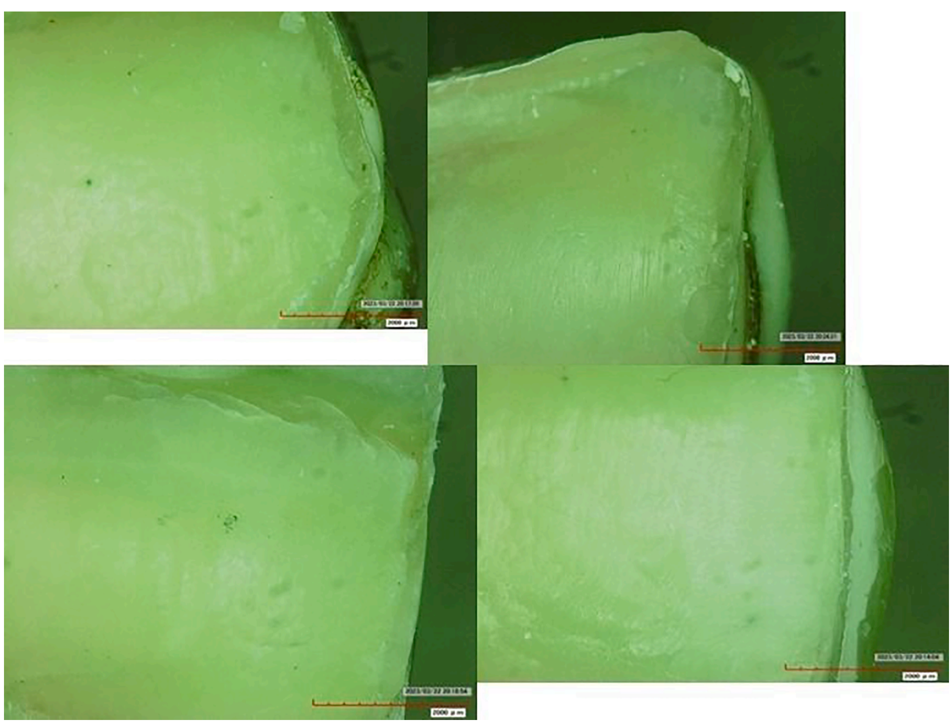

Fig. 7. The surface characteristics under a digital microscope for four samples from the micro-abrasion 45-second group.

Currently, sandblasting is employed in various dental procedures to improve treatment results. For example, sandblasting the inner or fitting surface of restorative dental materials, such as zirconia, with aluminum oxide particles enhances the shear bond strength between resin-luting materials and dental restorative materials (Nishigawa et al., 2016).

Sandblasting with aluminum oxide particles has been proven to improve the bond strength between artificial teeth and resin (Consani et al., 2010).

The micro-tensile bond strength of (LAVA) CAD/CAM resin blocks has been shown to increase with the use of a sandblasting procedure, thereby enhancing the restoration's survival rate (Tekçe et al., 2019). A separate study indicates that sandblasting zirconia crowns improve their shear bond strength by increasing surface area and roughness. One downside of this technique, though, is the formation of micro-cracks that

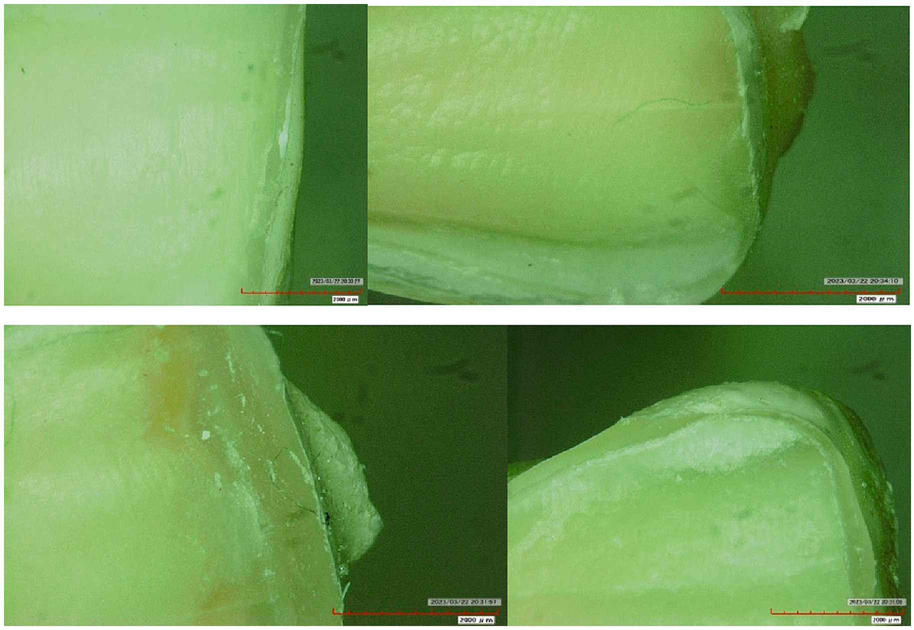

Fig. 8. The surface characteristics under a digital microscope for four samples from the conventional + micro-abrasion 30-second group.

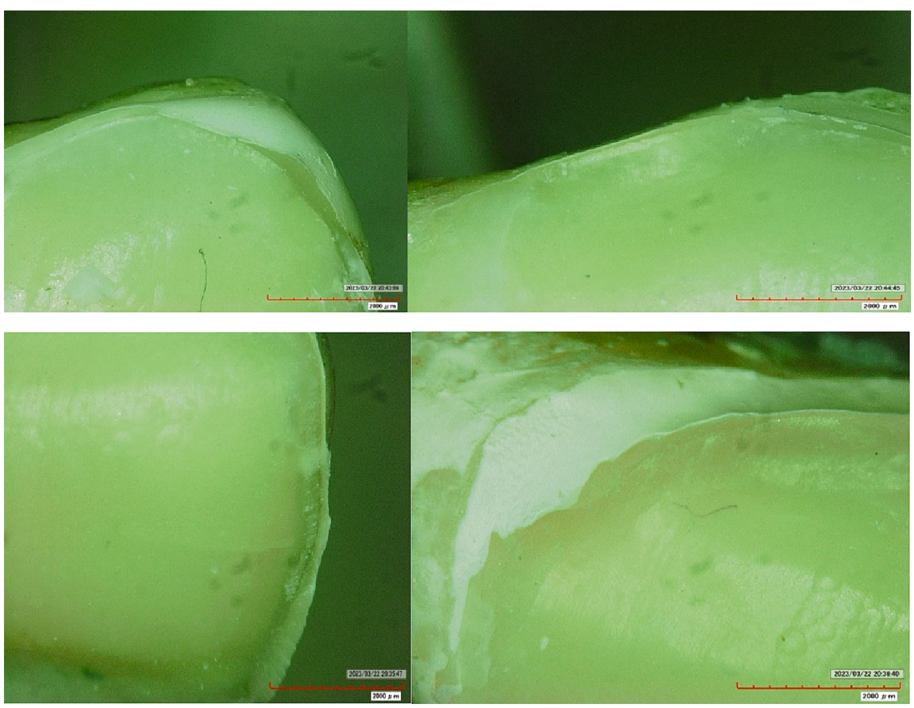

Fig. 9. The surface characteristics under a digital microscope for four samples from the conventional + micro-abrasion 45-second group.

Table 2
Modes of failure and surface characteristics for all samples in all groups.

Group	Failure type		
	Adhesive	Cohesive	Combination
1	4	–	6
2	3	2	5
3	2	4	4
4	1	5	4
5	1	7	2

Table 3
The shear bond strength means, median, and Standard deviation for all the groups measured in mega-pascals (Mpa).

Group Number	Shear Bond Strength					
1	mean	9.008265	median	9.151145	SD	1.045845
2	mean	13.48699	median	13.89433	SD	2.05915
3	mean	17.92675	median	17.70709	SD	1.884358
4	mean	21.50881	median	21.1257	SD	1.703575
5	mean	25.69446	median	25.63484	SD	1.87125

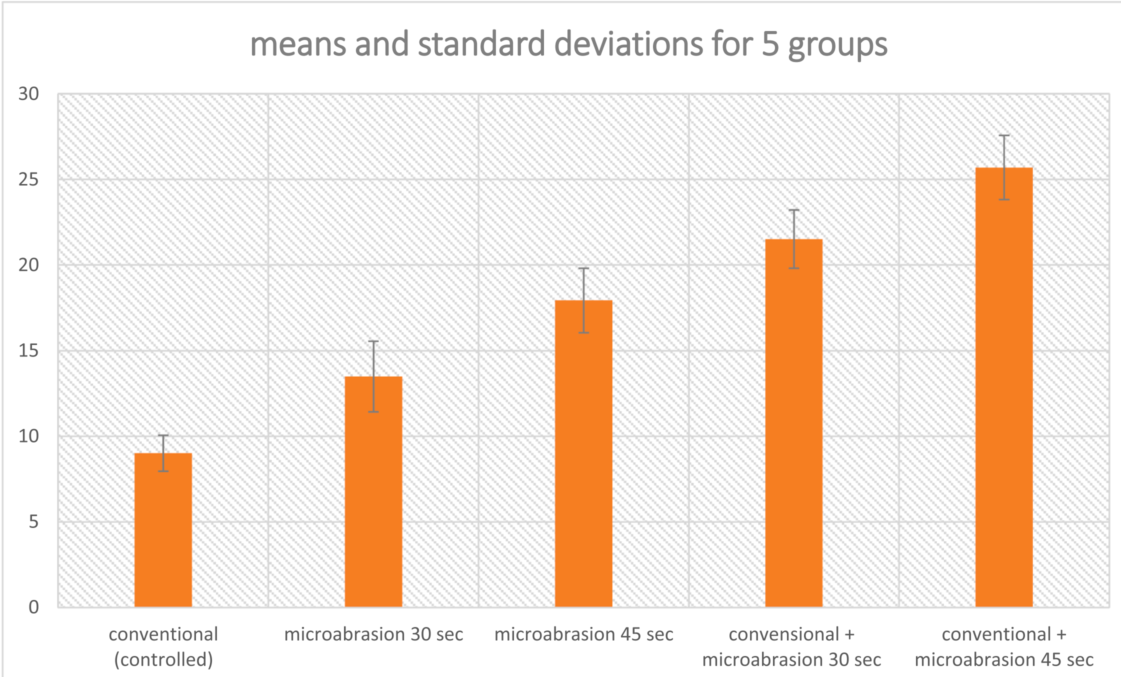

Fig. 10. Means and standard deviations for all the groups. Group 1 have the least mean and standard deviation. Group 2 have the highest standard deviation. Group 5 have the highest mean.

could potentially weaken the zirconia. However, this issue is mitigated by the resin cement, which flows into these micro-cracks, thereby raising the zirconia's strength. Also, silica particles not only augment the roughness of the surface but also promote chemical retention by facilitating the bonding of silane and the silica-coated zirconia surface (Altan et al., 2019). Instead of replacing the entire restoration, repairing a fractured or chipped ceramic restoration is often preferred. Before repairing with composite, the chipped ceramic surface must be beveled 2 mm wide around the damaged site. This should be followed by surface preparation with fine diamond burs and airborne particle abrasion – processes that primarily enhance the bond strength between the ceramic and the composite (Duzyol et al., 2016).

Sandblasting, a procedure known for removing unwanted oxides and contaminants, can also increase surface roughness. By doing so, surface energy and bonding surface area are effectively enhanced. Specifically, for orthodontic bands and brackets, sandblasting has been shown to boost bonding strength and retention by 27 %, as well as improve the median survival rate. Such results underline the potential for directly sandblasting enamel as a feasible technique for preparing bracket bonding in orthodontics. Another study suggests that the enamel surface is not damaged by sandblasting, making it a viable alternative to pumice polishing. However, sandblasting enamel is considered a highly intricate procedure. Variables such as particle size, pressure used in sandblasting, and duration need to be considered to optimize the abrasion result (Chung et al., 2001).

This study revealed that sandblasting teeth with aluminum oxide particles can positively enhance their shear bond strength. While this technique can also be combined with other methods to further increase shear bond strength, it should be used cautiously to avoid harm to patients and dental staff. To mitigate this, protective measures such as using a rubber dam to prevent patients from ingesting the particles, wearing eye goggles, and employing high-volume evacuation to limit particle scattering should be implemented.

Additionally, the surface characteristics of teeth play a crucial role in defining the strength of a labial veneer restoration. Using mechanical intervention to roughen the teeth increases shear bond strength. Therefore, teeth treated with mechanical intervention demonstrate greater cohesive strength. In other words, combining aluminum oxide particles with phosphoric acid etchant during sandblasting results in higher bond strength between the tooth structure and the cement than using the etchant alone.

However, extending the duration of sandblasting can increase shear bond strength but may damage the tooth structure. Hence, using smaller-sized aluminum oxide particles can prevent this potential harm.

The study's limitations include using only a single type of cement, one size of aluminum oxide particles, and only examining sound (caries-free) teeth. Consequently, further investigations are necessary to evaluate shear bond strength using different cement types, particle sizes and teeth with caries.

5. Conclusion

The study evaluated the effectiveness of various techniques to improve the adhesion of labial veneers. Of all the methods tested, sandblasting proved superior in achieving optimal adhesion. This is credited to sandblasting's ability to create a micro-roughened surface that enhances the bond strength between the veneer and the tooth. However, excessive enamel reduction during tooth surface preparation can negatively impact the tooth's overall structure and function. So, caution is advised to not over-prepare the teeth. A conservative approach should be adopted in tooth surface preparation for the veneer restoration to ensure its long-term success.

In summary, these findings indicate that sandblasting and increasing surface tension through conditioning can effectively enhance the adhesion of labial veneers. Nonetheless, the use of appropriate techniques and meticulous assessment of enamel reduction during tooth preparation is imperative for optimal long-term results.

Ethical approval

The College of Dentistry Research Center (CDRC) at King Saud University granted ethical authorization for this study (Registration No. #IR 0437, IRB Research Project No. E – 22-7187). The research employed an in vitro lab trial design, which was approved and deemed free of ethical conflicts due to the absence of direct experiments or lab tests on human subjects or actual patients.

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None.

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