Egyptian
Orthodontic Journal

EFFECT OF SURFACE TREATMENT METHODS OF PORCELAIN DISCS ON THE SHEAR BOND STRENGTH OF TWO ORTHODONTIC ADHE SIVES (AN IN VITRO STUDY)

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ABSTRACT:

Introduction: *Ceramic is an inert material. Mechanical or chemical ceramic surface preparation is needed prior to the bonding such as Microetcher II for mechanical surface preparation while hydrofluoric acid for chemical surface preparation. Composite resin is a hydrophobic material while cyanoacrylate is a hydrophilic one.* ***Objective:*** *The aim of the study was to study and compare the effect of surface treatment methods of porcelain discs on shear bond strength of two orthodontic adhesives (light cure composite resin and light cure cyanoacrylate).* ***Materials and Methods:*** *The study was conducted on ninety eight feldspathic circular glazed porcelain discs divided into two main groups* ***Group A (N=8)*** *which was examined by* ***SEM*** *to determine the effect of the surface treatment methods on the surface texture (micropores) and to compare it with the two untreated discs and* ***Group B (N=90)*** *which was divided into six subgroups of fifteen; these specimens were used for the shear bond strength testing, three subgroups bonded by composite resin and three subgroups bonded by cyanoacrylate.* ***ARI*** *were measured after debonding for the specimens under* ***SEM.*** *The statistical*

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*analysis was carried out using SPSS program **(SPSS, 2008).** Cross tabulation and Chi square test were used to test the ARI. **Results: Subgroup 1** (composite after sandblasting and acid etching) showed the highest shear bond strength among all subgroups with mean16.27 MPa followed by **Subgroup 3** (composite after acid etching) with mean 14.96 Mpa, **Subgroup 4** (cyanoacrylate after sandblasting and acid etching) with mean13.32 MPa, **Subgroup 6** (cyanoacrylate after acid etching) with mean 12.47 MPa, **Subgroup 2** (composite after sandblasting) with mean 7.86 MPa **Subgroup 5** (cyanoacrylate after sandblasting) had the lowest shear bond strength among all subgroups with mean 6.63 MPa.*

Conclusions: *Composite subgroups had higher shear bond strength than cyanoacrylate subgroups, but cyanoacrylate results were in the clinically acceptable range.*

Keywords: *Shear bond strength, Scanning electron microscope, Adhesive remnant index, Micropores, Microetcher II, Hydroflouric acid, Composite resin, Cyanoacrylate*

INTRODUCTION

Ceramic is an inert material, so it doesn't adhere to the available bonding resins, therefore ceramic surface preparation is an essential step. Hence, mechanical (surface roughness) or chemical (porcelain etching) alterations or both are essential.

Many advances in materials and techniques that are effective for bonding to non–enamel surfaces can be done such as the use of the Microetcher II which uses 50 µm or 90 µm aluminum oxide particles at different pressures.

Conventional composite resin orthodontic adhesives have a series of technique sensitive steps that require dry etched enamel for mechanical adhesion due to their hydrophobic properties.

Cyanoacrylate adhesives have been utilized in different fields of dentistry and medicine as tissue adhesives and sealing materials. Also, they have been used in orthodontics. One of the significant advantages of cyanoacrylate adhesives is their ability to polymerize as a thin film at room temperature, without a catalyst, when pressure is applied in a moist environment. The setting is initiated by pressure or water.

Cyanoacrylate bonds to wet surfaces and is moisture activated. The surface of the etched enamel can be completely covered with water just prior to bonding. It solves the problems faced by the orthodontist during bonding in an environment with increased salivary contamination for example as partially erupted premolars especially in the mandibular arch, or with increased blood contamination as surgically exposed canines.

A new light-cured cyanoacrylate adhesive (Smart Bond LC) was introduced in the orthodontic market, and delivered as a gel adhesive that can bond to both dry and wet surface.

MATERIALS AND METHODS

Nighty eight discs (Duceram Kiss, D A2, Dentsply. Germany) 10 mm diameter × 3 mm thickness were flattened, smoothed, polished and glazed by Low machine in National Research Centre and were grouped into two main groups ; **Group A** and **Group B**

Flattening and smoothing machine

Group A (**N=8**) was divided into 4 equal subgroups and were examined by **SEM** (Joel, JXA-840A Electron Probe Microanalyzer, Japan) at original magnification (× 700, × 1500, × 3000) to determine the effect of the surface treatment methods on the surface texture (micropores) and to compare it with the two untreated discs, where **2** discs were remained glazed without change (act as a control group), **2** discs surface treated with sandblasting and hydrofluoric acid, **2** discs were surface treated with sandblasting only, and **2** discs were surface treated with acid etching only.

Scanning Electron Microscope (SEM)

Group B (**N=90**) used for bonding and shear bond strength testing, was divided into six subgroups (**N=15**) according to the type of the adhesive and the method of the surface treatment used (**1, 2, 3, 4, 5 and 6**).

Composite subgroups (N=45) where light cure conventional composite resin (Transbond XT, 3M Unitek, Monrovia, CA, USA) was used; it was divided according the method of surface treatment used.

Subgroup 1 (N=15): Fifteen metal brackets were bonded to fifteen porcelain discs with conventional light cure composite resin after 2 successive surface treatments were made with Sandblasting with microetcher II (Intraoral Sandblaster. Danville. USA) for 10 seconds at 10 mm, and acid etching with 9.6 % hydrofluoric acid (Ultradent, Utah, USA), for 2 minutes, then applying silane coupling agent (Ultradent, Utah, USA).

Subgroup 2 (N=15): Fifteen metal brackets were bonded to fifteen porcelain discs using conventional light cure composite resin, after surface treatment with sandblasting only with microetcher II for 10 seconds, at 10 mm, then applying silane coupling agent.

Subgroup 3 (N=15): Fifteen metal brackets were bonded to fifteen porcelain discs using conventional light cure composite resin after surface treatment with acid etching only with 9.6% hydrofluoric acid for 2 minutes, then applying silane coupling agent.

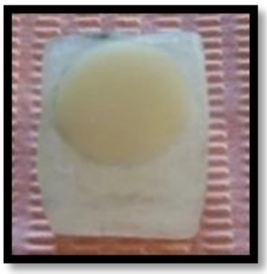
Cyanoacrylate subgroups (N=45) where light cure orthodontic cyanoacrylate (Smart Bond LC, Gestenco International AB, Gothenburg. Sweden) adhesive was used; they were divided according the method of surface treatment used.

Subgroup 4 (N=15): Fifteen metal brackets were bonded to fifteen porcelain discs with light cure cyanoacrylate after 2 successive surface treatments were made ; Sandblasting with Microetcher II for 10 seconds at 10 mm and acid etching with 9.6 % hydrofluoric acid for 2 minutes, then applying silane coupling agent.

Subgroup 5 (N=15): Fifteen metal brackets were bonded to fifteen porcelain discs using light cure cyanoacrylate after surface treatment with sandblasting only with Microetcher II for 10 seconds at 10 mm, then applying silane coupling agent.

Subgroup 6 (N=15): Fifteen metal brackets were bonded to fifteen porcelain discs using light cure cyanoacrylate after surface treatment with acid etching only with 9.6 % hydrofluoric acid for 2 minutes, then applying silane coupling agent.

Group B specimens were mounted on clear self-cure acrylic resin (Acrostone, Cold cure denture base acrylic resin, England.) cubical blocks (1.3x1.3x1.5 cm). The discs were embedded in the acrylic resin with the unglazed disc surface toward the acrylic resin where the glazed surface is up uncovered and numbered according to the subgroups.



Clear acrylic resin block.

Metal brackets that were used in this research were Roth 0.22”, 3M, Unitek, Monrovia, CA, USA.

All ninety specimens were stored in distilled water for 24 hours before shear bonding test.

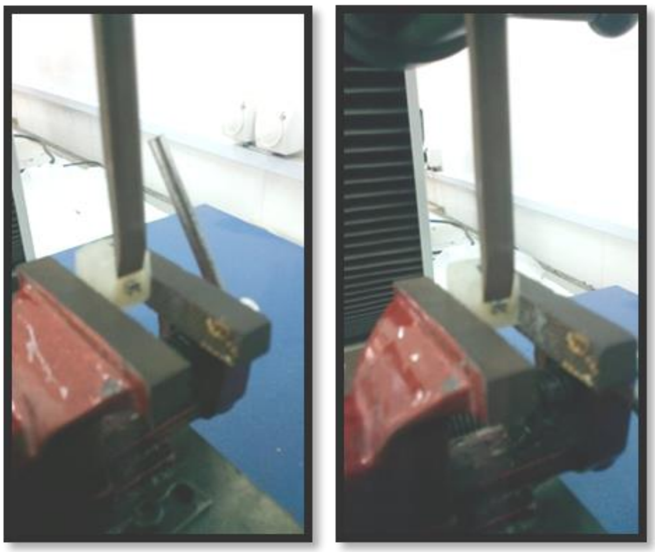
Shear bond testing was done by using a computerized Instron universal testing machine (TIRA test 2805, Instron Universal Testing Machine.Germany) at crosshead speed of 5 mm/minute.

Instron universal testing machine

The forces of fracture of all specimens were recorded and analyzed to compare the shear bond strength between the six subgroups.

The force required to debond each bracket was recorded in Newtons (N) and transferred into megapascals (MPa) by dividing the force by the surface area of the mesh back of the bracket (11.4 mm^2).

$$\text{Shear bond strength (SBS)} = \frac{\text{Force in Newtons (F)}}{\text{The bracket base surface area (SA)}}$$



Shear bond strength testing

The debonded surfaces of porcelain were examined by visual scoring to determine the **ARI** (Adhesive remnant index) and the scores were recorded. Images were taken to some samples from the subgroups by **SEM.**

The **ARI** scale has a range from **0** to **4:**
Score 0 = No adhesive left on the porcelain.
Score 1 = Less than half of the adhesive left on the porcelain.
Score 2 = More than half of the adhesive left on the porcelain.

Score 3 = All adhesive left on the porcelain, with distinct impression of the bracket meshwork.

Score 4 = P.F. = Porcelain damaged or fractured.

Statistical analysis was carried out using SPSS program **(SPSS, 2008)**

Two ways analysis of variance was used to test the effect of adhesive, surface treatment and their interaction on shear bond strength.

One way analysis of variance was used to test the effect of technique (adhesive + surface treatment) on shear bond strength.

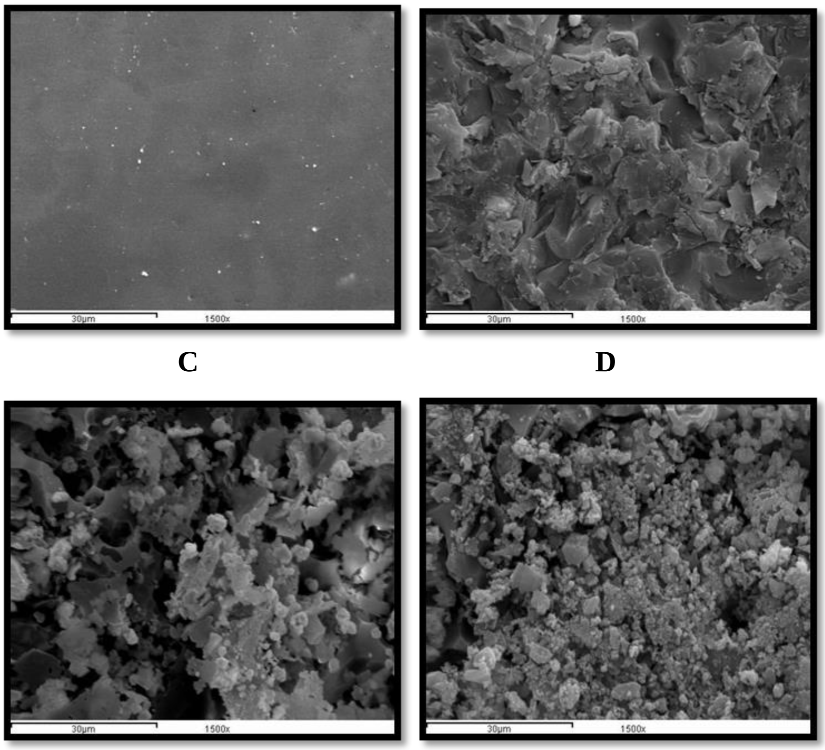
Student t test was used to test the effect of adhesive on shear bond strength within each surface treatment.

Cross-tabulation and Chi square test were used to test the effect of technique on the Adhesive remnant index after debonding.

RESULTS

The SEM of the eight discs of Group **A** showed that the surfaces treated with both sandblasting and acid etching showed major microporosities and microroughness in a morphological pattern (showed numerous deep irregularities, gaps and undercuts together with white spots of HFA and surface erosions created by sandblasting) followed by the two acid etched discs which showed moderate microporosities (showed deep irregularities and undercuts together with the white spots appeared due to HFA partially dissolved the polymer and glassy phases of the ceramics), then the two sandblasted discs respectively, which showed minor microporosities (showed a uniform surface peeling pattern with superficial erosions) under SEM in comparison with the two untreated discs.

A **B**



Scanning electron microscope photographs of:

(A) Glazed porcelain surface of untreated disc**,**

(B) Minor microporosities of sandblasted disc**,**

(C) Moderate microporosities of acid etched disc**,**

(D) Major microporosities of sandblasted and acid etched disc**,** Original magnification ×1500.

Group B: Duncan`s Multiple Range test for multiple comparisons revealed that shear bond strength for Sandblasting + HFA was significantly higher than the other two subgroups followed by HFA only which was significantly higher than sandblasting only (P-value < 0.05) in Composite and Cyanoacrylate Subgroups.

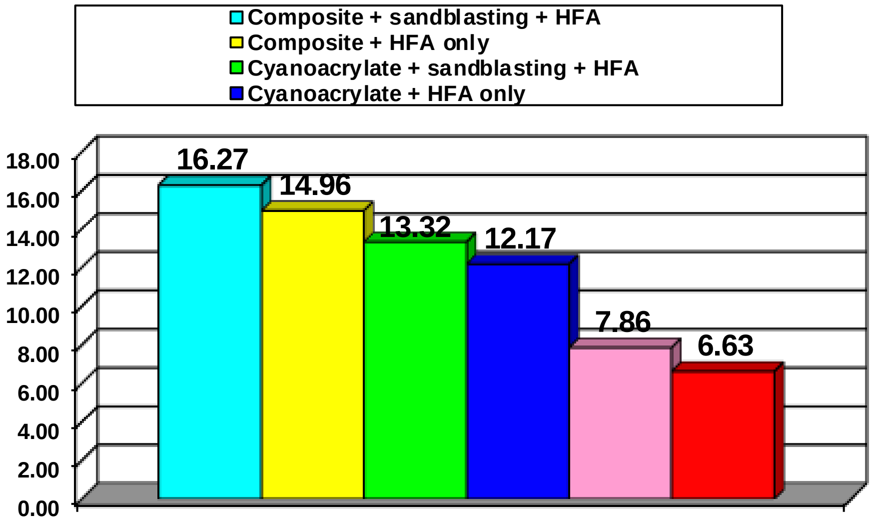
Regarding sandblasting surface treatment and Hydrofluoric acid etching, the mean values of shear bond strength were significantly (P≤ 0.001) higher in composite adhesive than in Cyanoacrylate adhesive in all subgroups.

Regarding sandblasting surface treatment only, the mean values of shear bond strength for different subgroups (**2** and **5**) were (7.86) and (6.63) Mpa respectively. Student`s t-test revealed significant difference between both subgroups as (P-value < 0.05).

Regarding Hydrofluoric acid etching only, the mean values of shear bond strength for different subgroups (**3** and **6**) were (14.96) and (12.17) MPa respectively. Student`s t-test revealed a significant difference between both subgroups as (P-value < 0.05).

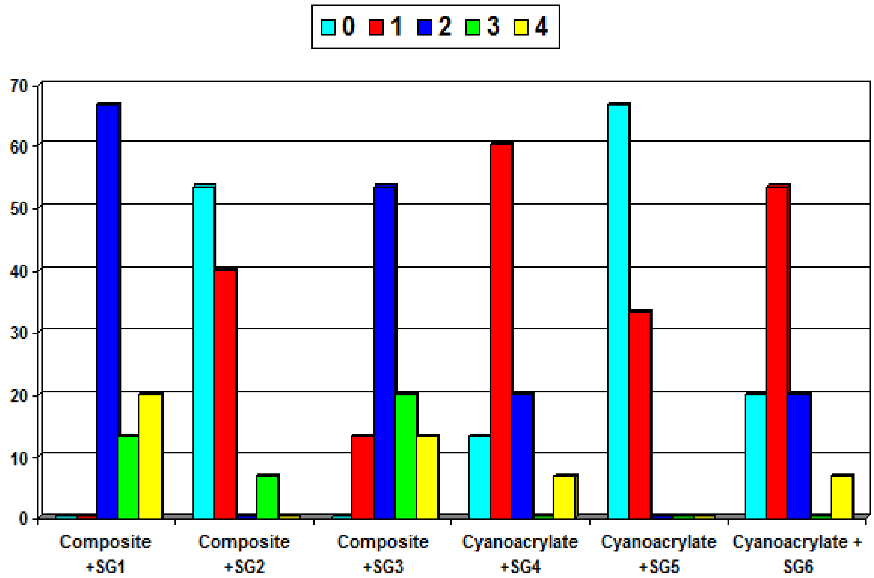
Regarding Sandblasting surface treatment and Hydrofluoric acid etching together, the mean values of shear bond strength for different subgroups (**1** and **4**) were (16.27) and (13.32) Mpa respectively. Student`s t-test revealed significant difference between both subgroups as (P-value < 0.05).

Ranking for the effect of technique (adhesive + surface treatment) on shear bond strength in mega pasacal, in a descending manner showed that Subgroup **1** (16.27 MPa) > Subgroup **3** (14.96 Mpa) > Subgroup **4** (13.32 MPa) > Subgroup **6** (12.47 MPa) > Subgroup **2** (7.86 MPa) > subgroup **5** **(**6.63 MPa). There were significant differences between all subgroups.



Ranking of mean shear bond strength in megapascal in different techniques (adhesive + surface treatment).

ARI results were by performing Chi square test between different indices for both adhesives, it was revealed that there were significant and insignificant differences between certain subgroups.



Prevalence of ARI in different groups

Subgroup **5** had the highest value of score **0** in which no adhesive was left on porcelain followed by subgroups **2, 6** and **4** respectively. Score **4** (porcelain fracture) wasn't noticed in subgroups **2** and **5**, in which there was insignificant difference between subgroups **2** and **5** in **ARI** (P-value = 0.05).

Subgroup **1** had the highest value of score **4** (porcelain fracture) and score **2** (in which more than 50 % of the adhesive was left on the surface), followed by subgroup **3**, **4** and **6** respectively.

Where subgroup **3** had the highest value of score **3** (in which all adhesive was left on porcelain surface with distinct impression of the bracket meshwork) followed by subgroup **1** and **2** respectively, in which there was an insignificant difference between subgroups **1**and **3** in **ARI (P-value = 0.05).**

Subgroup **4** had the highest value of score **1**(less than half of the adhesive was left on porcelain surface) followed by subgroup **6**, **2** and **5** respectively. Both subgroups **4** and **6** almost had the same values of score **4** (porcelain fracture) and score **2** (in which more than 50 % of the adhesive was left on the surface).

Where subgroup **6** was higher in score **0** (no adhesive was left on porcelain) than subgroup **4**, there was insignificant difference between both subgroups in **ARI (P-value = 0.05)**.

DISCUSSION

This study has been carried out due to the increased number of adults seeking orthodontic treatment that makes clinicians often bond orthodontic brackets to teeth that have different types of restorations. One of the materials that particularly had presented problems to orthodontist is porcelain surface.

Polishing and glazing are important to strengthen the ceramic surface reducing crack propagation, and increasing the fracture resistance.

The results of the shear bond strength test were in the clinically accepted range which is sufficient for the clinical use that adequate bond forces should range from **6** to **8** MPa in vitro, but it should be higher in vivo because it may be affected by the environmental conditions in the mouth.

Use of silane coupling agent, which is important in bonding to porcelain in composite subgroups is one of the reasons of the significant increase in shear bond strength in composite subgroups than cyanoacrylate subgroups, this is because it increases the wetting and penetration of resin into microporosities of porcelain surface. In addition, silane functions to provide a chemical link between oxide groups in porcelain (inorganic part) and polymer molecules of the resin (organic part), thus forming a bridge between the two materials.

In **ARI** results, Composite subgroups especially **subgroup 1** (sandblasted by microetcher + acid etching by HFA) and **subgroup 3** (acid etched by HFA) showed more cohesive failures in porcelain

(porcelain fracture) than the cyanoacrylate subgroups which means that they had stronger bond strength than cyanoacrylate subgroups.

Subgroup 1 (sandblasted by microetcher + acid etching by HFA) showed highest level of **score 2** (more than half of the adhesive left on porcelain surface) followed by **subgroup 3** (acid etched by HFA) which means that they had stronger bond strength than other subgroups, due to increased level of shear bond strength and cohesive failures in resin.

The discs treated with sandblasting and hydrofluoric acid etching together (**subgroup1** and **4**) and bonded with both adhesives showed more cohesive failures in porcelain (porcelain fracture) as well as subgroups treated with hydrofluoric acid etching alone (**subgroup 3** and **6**).

While the discs treated with sandblasting alone without acid etching (**subgoup 2** and **5**) especially **subgroup 5** bonded with cyanoacrylate showed more adhesive failures (**score 0**) (no adhesive left on porcelain surface) and no fracture to the porcelain surface**.**

Cyanoacrylate showed less damage to the porcelain surface than composite, especially **subgroup 5** (treated with sandblasting alone).

Subgroup 5 (treated with sandblasting alone) showed less or no adhesive remaining on porcelain surface (**Score 0** or **1**).

Cohesive failure in the ceramic material could indicate that the bond between the adhesive resin and the ceramic was stronger than the ceramic itself. When bond strength values between the ceramic and the composite resin exceeded 13 MPa, there would be cohesive fractures in the ceramic material as shown in **subgroups 1**, **3** and **4**.

CONCLUSIONS

- The SEM showed that the surfaces treated with both sandblasting and acid etching showed major microporosities in a morphological pattern, followed by the acid etched discs, then the sandblasted discs respectively, which showed minor microporosities under SEM when compared with the untreated discs.

- The use of sandblasting with Microetcher and acid etching with hydrofluoric acid increase the shear bond strength especially with the orthodontic composite resin.
- Composite subgroups had higher shear bond strength than cyanoacrylate subgroups, but cyanoacrylate results were in the clinically acceptable range (6 – 8 MPa).
- Cyanoacrylate had the lowest shear bond strength after sandblasting alone.
- Cyanoacrylate subgroups showed less adhesive remaining on the porcelain surface and less porcelain detachement especially after sandblasting alone.
- Hydrofluoric acid etching after sandblasting increased the shear bond strength, so, more adhesive remained on porcelain surfaces and more porcelain fracture had been observed especially when used with composite resin.

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