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THE EFFECT OF DIFFERENT ENAMEL SURFACE TREATMENT METHODS ON THE SHEAR BOND STRENGTH BETWEEN SELF-ADHESIVE RESIN COMPOSITE AND ORTHODONTIC BRACKETS

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ABSTRACT

Objective: The current research evaluated the shear bond strength (SBS) of orthodontic brackets with self-adhesive resin composite (Fusio) with different enamel surface treatment. **Materials and methods:** Twenty-eight maxillary premolars were divided according to bonding protocol into four groups (n=7). Group 1 brackets were bonded with orthodontic adhesive (Enlight) and primer (Orthosolo) after etching of enamel surface. The brackets of other three groups were bonded to enamel with Fusio but with different enamel surface treatment; group 2 brackets bonded directly, Group 3 brackets were bonded after enamel etching, while group 4 brackets were bonded with Fusio and Orthosolo after enamel etching. All samples were subjected to SBS followed by determination of adhesive remnant index (ARI) by stereomicroscope. The statistical significance difference was determined by Kruskal-Wallis and Mann-Whitney tests ($P \leq 0.05$). **Results:** Group 1 reported the highest statistically significant difference SBS values (25.66 MPa ± 3.82) followed by group 3 and 4 (11.92 MPa±1.88) (9.52 MPa ± 1.66) respectively with no statistically significant difference. However, group 4 recorded least statistically significant difference (5.56 MPa±1.33). ARI recorded the most adhesive remained at tooth structure in groups 1,3 and 4 and remained on the brackets in group 4. **Conclusion:** Self-adhesive resin composite can be used safely for bonding the orthodontic brackets provided that enamel surface etching.

KEYWORDS: Orthodontic brackets, shear bond strength, adhesive remnant index, self-adhesive resin composite.

INTRODUCTION

Achieving a dependable bond between orthodontic brackets and enamel of tooth is a critical parameter for the success of the orthodontic treatment [(1)]. The strength of bond between the tooth enamel and orthodontic brackets should be optimized, strong enough to withstand the debonding factors and weak enough to be easily broken without damaging tooth enamel after completion of treatment procedures [(2)].

Therefore, the bonding of orthodontic brackets to tooth enamel developed over last decades. Many pretreatment procedures to enamel surface have been suggested to achieve that suitable bond with enamel such as application of phosphoric acid, laser and air abrasion. This is followed by application of primer to that pretreated enamel surface [(2,3)].

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In an attempt to decrease the risk of clinical errors and the treatment time, development of self-adhesive resin composites was proposed by addition of self-etching or self-adhesive monomers. The addition of such acidic monomers (such as 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) or glycerol phosphate dimethacrylate (GPDM) to the resin composites resulted in a nanointeraction with the surface layer of tooth structure. This interaction involves demineralization of the tooth surface and resinous penetration within the tooth structure [(4)]. Therefore, these self-adhesive resin composites can bond micromechanically and chemically with the hydroxyapatites of tooth structure [(4)].

Unfortunately, many authors reported lower bond strength of self-adhesive resin composites in comparison with conventional resin composites with self-adhesive bonding systems [(4-6)]. However, this lower bond strength may afford a favorable condition during bonding of orthodontic brackets to tooth enamel to avoid enamel fracture during bracket removal after end of treatment.

Therefore, the aim of the present research was to assess shear bond strength (SBS) between enamel and metallic orthodontic brackets after different surface treatment methods to the enamel surface using self-adhesive resin composite. The tested null hypothesis was that the surface treatment of enamel before bonding of metallic brackets with self-adhesive resin composite has no effect on SBS and Adhesive remnant index (ARI).

MATERIALS AND METHODS

Sample size calculation:

The sample size was determined using G power version 3.1.9.6. (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) with a power of 95% and alpha error probability = 0.05 with a reference to mean and standard deviation values of a one-way ANOVA study [(7)]. The total sample size was 28 specimens (n=7) is required.

Teeth collection:

The institutional ethics committee, faculty of dentistry for boys, Azhar University, Cairo, Egypt, approved this research protocol (approval code 971/6526). A total of 28 Sound first maxillary premolar teeth extracted due to orthodontic reasons were gathered from the outpatient clinic, oral surgery department, Faculty of Oral and Dental Medicine, Modern University for Technology and Information, Cairo, Egypt.

The collected teeth were cleaned using pumice with rubber prophylaxis cup at low speed and then, disinfected by immersion at 37°C into 0.2% thymol for 48 hours. After disinfection, they stored in physiologic saline at 4° C that was changed weekly and the teeth were used within 2 months [(8)].

Materials:

The materials tested in the current study were declared in table 1.

TABLE (1) The adhesive materials used in the study

Material/ Specification	**Manufacturer**	**Lot number**
Enlight Light cured orthodontic adhesive resin	Ormco Corporation, CA, USA	740-0198
Orthosolo Bond enhancer		
Fusio Liquid Dentine Self-adhesive flowable composite	Pentron™, CA, USA	N21SC

Samples grouping

The teeth were divided horizontally 2mm below cemento-enamel junction, embedded inside an acrylic mold. Then the teeth were divided randomly according to the bonding protocol into 4 groups (using Microsoft Office Excel 2019 (Microsoft Corporation, Redmond, WA, USA)).

In Group 1, bonding area of tooth enamel was etched by 37% phosphoric acid etchant solution (Ormco Corporation, Orange, CA, USA) 30 seconds, rinsed then dried by compressed air for 5s for each step [(3)]. Primer (Orthosolo) was painted to the tooth surface in a thin layer. A suitable amount of orthodontic adhesive (Enlight) was added to the metallic bracket base (Roth prescription bracket, mini 2000, Ormco Corporation, Orange, CA, USA). Then bracket was placed on enamel surface with firm pressure. Removal of excess adhesive was made with hand instrument, followed by curing with LED curing unit for 20s at 1500W/cm^2 (Radii Plus, SDI Limited, Australia).

In group 2: A suitable amount of self-etch resin composite (Fusio) was added to bracket base and bonded to tooth structure as mentioned before. In group 3, the enamel surface was etched as discussed in group 1 and the bracket bonded to tooth surface using Fusio as mentioned before. In group 4, enamel etching was done as mentioned before then painted with primer (Orthosolo). The bracket was bonded to tooth surface using Fusio as mentioned in previous groups (Table 2).

Table (2) The bonding procedures of tested groups.

	Phosphoric acid etching	Primer application	Enlight application	Fusio application
Group 1	●	●	●	
Group 2				●
Group 3	●			●
Group 4	●	●		●

Shear bond strength test:

Before testing, samples were checked at 30X by light stereomicroscope (Nikon MA100 Japan) to ensure a good interface without any air bubbles or gaps. SBS was calculated using universal testing machine (Instron® model-3345, England). The sample was attached to the lower fixed part of the machine and a uni-beveled chisel (0.5 mm width blade) is fixed at the upper movable head of the machine. The bracket/enamel interface was neared as possible to the chisel blade. A compression force at a crosshead speed of 1.0 mm/min was applied by the chisel blade until sample failure. SBS (MPa) was calculated by dividing the force required for failure by the bracket surface area (mm^2) by machine software BlueHill 3 Instron®, England.

Failure mode determination:

Both teeth and brackets of all groups were inspected at 30X with a light stereomicroscope (Nikon MA100 Japan) to determine the interface after debonding. The assessment and scoring of the remaining adhesive were done according to the modified adhesive remnant index (ARI) [(3,9)]

The scoring criteria of the index are as follows:

- **Score 1** = all of adhesive remains on the tooth.
- **Score 2** = more than 90% of adhesive remains on the tooth.
- **Score 3** = from 10% to 90% of adhesive remains on the tooth.
- **Score 4** = less than 10% of adhesive remains on the tooth.
- **Score 5** = no adhesive remains on the tooth.

Statistical analysis

The mean and standard deviation values were calculated for each group. The collected data showed not normal and non-homogenous distribution after testing with Levene's test and Kolmogorov-

Smirnov test. The statistically significant difference between all groups was determined by Kruskal-Wallis test followed by Mann-Whitney to determine the statistically significant difference between each two groups. The Significance level was set at 0.05. Statistical analysis was done by IBM SPSS Statistic (Armonk, New York, USA), version 25 for Windows.

RESULTS

The highest statistically significant SBS value was recorded by bonding of orthodontic brackets with group 1 (25.66 MPa±3.82) followed by bonding with group 3 and group 4 (11.92MPa±1.88 and 9.52MPa±1.66) respectively with no statistically significant difference between group 3 and 4 Finally, group 2 recorded the least statistically significant SBS (5.56 MPa±1.33) (Table 3 and Table 5).

The ARI distribution of all groups was showed in Table 4. Regarding group 1; five samples were recorded with score 5 and one sample was recorded in both score 1 and 3. Regrading group 2, five samples recorded with score 5 and two samples were recorded in score 4. Regrading group 3; four samples reported score 1, two samples reported score 2 and only one sample reported score 4. Finally, group 4 reported six samples with score 2 and only one sample with score 1. Moreover, only group 2 reported statistically significant difference with other three groups (Table 5).

TABLE (3) Shear bond strength (MPa) of the all groups.

Group	Mean (MPa)	SD	P value
Group 1	25.66 a	3.82	0.000*
Group 2	5.56 c	1.33	
Group 3	11.92 b	1.88	
Group 4	9.52 b	1.66	

**: indicates significant difference between groups at p≤0.05 using Kruskal-Wallis test.*

Different letter indicates statistical difference between groups at p≤0.05 using Mann-Whitney test.

TABLE (4) Distribution of Adhesive Remnant Index (ARI) scores

Group \ Score	1	2	3	4	5	P value
Group 1	1	5	1			0.001*
Group 2				2	5	
Group 3	4	2		1		
Group 4	1	6				

**: indicates significant difference between groups at p≤0.05 using Kruskal-Wallis test.*

TABLE (5) Statistical significance between groups in SBS and ARI.

Test	1 Vs 2	1 Vs 3	1 Vs 4	2 Vs 3	2 Vs 4	3 Vs 4
P Value (SBS)	0.001 *	0.001 *	0.001 *	0.001 *	0.001 *	0.053 NS
P Value (ARI)	0.001 *	0.318 NS	0.71 NS	0.001 *	0.001 *	0.383 NS

**: indicates significant difference between groups at p≤0.05 using Kruskal-Wallis test.*

NS: indicates no significant difference between groups at p≤0.05 using Mann-Whitney test.

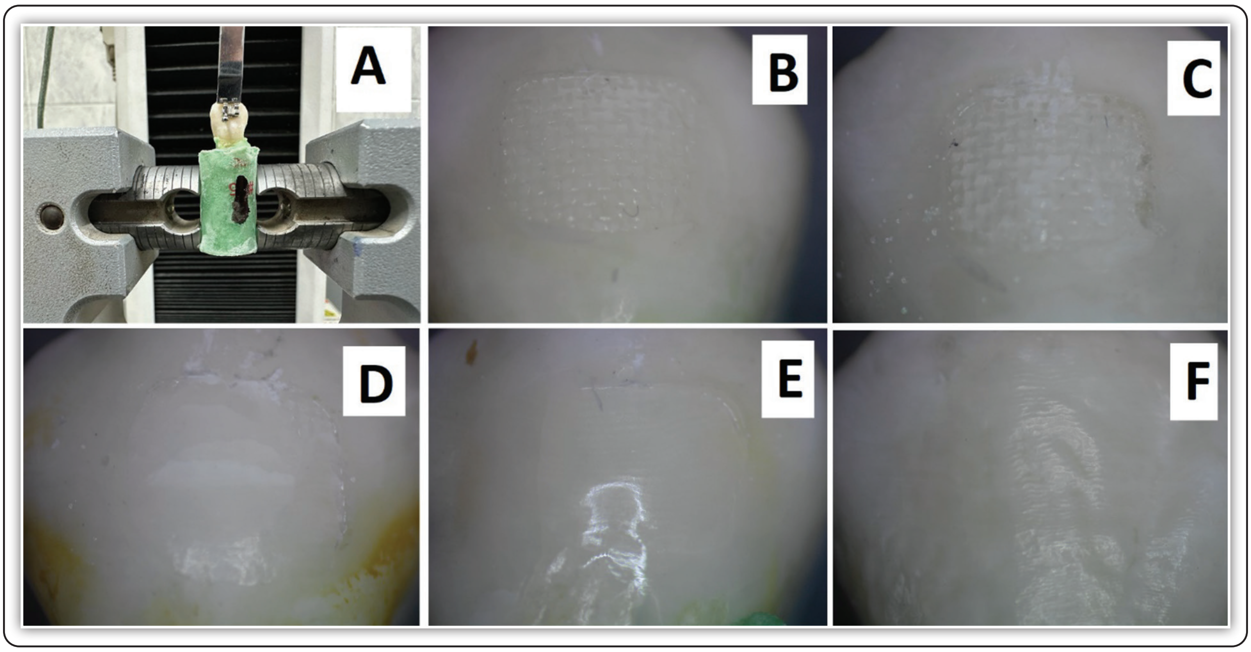

FIG (1) **A:** Sample subjected to shear bond strength test, **B:** Representative microscopic image showing score 1 mode of failure, **C:** Representative microscopic image showing score 2 mode of failure, **D:** Representative microscopic image showing score 3 mode of failure, **E:** Representative microscopic image showing score 4 mode of failure, **F:** Representative microscopic image showing score 5 mode of failure.

DISCUSSION

The optimized bond strength between tooth enamel and the orthodontic brackets is a mandatory criterion. Lowering the bond strength leads to frequent debonding of the brackets and subsequently interfering in the orthodontic treatment plan. On the other hand, higher bond strength may result in enamel damage during debonding procedure (10). However, Reynolds stated a minimum bond strength of orthodontic brackets ranging from 5.9 to 7.9 MPa for achieving a successful clinical bonding (11).

The design of the present study was to examine if the lower bond strength of the self-adhesive resin composites can afford the optimum bond strength between enamel and the orthodontic brackets. Therefore, an orthodontic adhesive system (Enlight) was used to compare the SBS with self-adhesive composite. Enlight was chosen because of its availability in the Egyptian market and because many authors reported its good and reliable bond strength values in many studies (12-14). The evaluation of the bond strength was assessed by shear strength because of its reliable results with more simulation to the clinical conditions (15).

The present study reported that the highest SBS was recorded in group 1 that used Enlight with Orthosolo after etching of enamel surface. Many studies found the same results. Sharma et al., (16) Bayani et al., (17) and Delavarian (18) referred the increase in the SBS of the orthodontic brackets when using Orthosolo to the incorporation of glass fillers within Orthosolo act as a shock absorber and subsequently reducing crack incidence that leads to bond failure.

Moreover, the current work reported no significant difference in SBS between group 3 and 4. The enamel surface in both groups was etched by 37% phosphoric acid before application of Fusio. However, the both groups reported a statistically significant difference than group 2 in which the

Fusio was applied directly over enamel surface. Therefore, the null hypothesis regarding the SBS was rejected.

Mine et al., [19] scanned the composite-enamel interface using transmission electron microscope (TEM) and found that the etching of enamel surface using phosphoric acid resulted in removing surface aprismatic layer of enamel. Despite of high acidity of self-adhesive monomer, incorporated within self-adhesive resin composite, it cannot dissolve nor penetrate that aprismatic enamel layer. Therefore, the authors found that etching of enamel surface with phosphoric acid improves the bonding with self-adhesive resin composite.

Moreover, Sibai et al., [20] recorded the positive impact of enamel surface etching with phosphoric acid on SBS with self-adhesive resin composite. They claimed that phosphoric acid etching increases the roughness of enamel surface and creates micro-spaces that resulted in more resin penetration within enamel.

Nevertheless, results of group 1 reported statistically significant higher bond strength in comparison with group 3 and 4. This could be explained by using a uniform layer of bond enhancer (Orthosolo) with its lower viscosity in comparison with self-adhesive resin composite. High adhesive viscosity leads to a decrease in the wettability and strength of the adhesive bond [21].

Although the results of group 1 are statistical significantly higher than group 3 and group 4, but when refereeing to Reynolds [13] values of acceptable bond strength values, group 3 and group 4 bonding protocols are reliable.

Furthermore, the current study measured ARI after brackets debonding. ARI is a widely used way to analyze interface after the bond failure between enamel and adhesive as well between adhesive and bracket. Moreover, ARI can determine the amount of enamel damage after bracket debonding [9,22].

If the bracket debonding happened at the adhesive-enamel interface, it means a high risk for enamel damage. On contrary, if the debonding happened at the adhesive-bracket interface, the tooth enamel is mostly conserved [22]. Therefore, the safest ARI score on enamel is score 1 and 2 as the remnant of resin composite is attached to enamel.

The current research revealed that most bond failure occurs within the reliable groups (1,3 and 4) gained score 1 and 2 (19 samples from 21) which means that the three bonding protocols of groups 1,3 and 4 are reliable protocols regarding the bond strength and enamel preservation. Therefore, the null hypothesis regarding ARI was rejected.

CONCLUSION

Under the circumstances of the present research, it can be concluded that:

1. Direct application of self-adhesive resin composites over enamel did not achieve the minimum requirements as a safe and reliable orthodontic brackets adhesive material.
2. Surface pretreatment of enamel using phosphoric acid alone or with application of primer improve the performance of self-adhesive resin composites to a safe and reliable orthodontic adhesive material.

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