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ORIGINAL ARTICLE

Can dentin surfaces be bonded safely with total-etch and self-etch systems?

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ABSTRACT

Objective: To assess and compare the shear bond strengths (SBSs) of orthodontic brackets bonded to enamel and dentin surfaces by using total-etching and 3 different self-etching adhesives. **Materials and Methods:** A total of 160 extracted mandibular incisors were randomly divided into 4 groups. In Group I, the hard tissue was etched with 37% phosphoric acid; in Group II, Transbond Plus Self Etching Primer (TSEP) system was used; in Group III, Clearfil Tri-S Bond Plus was used; and, in Group IV, AdheSE was used. Each group was divided into 2 subgroups: The enamel surfaces were conditioned in subgroup-A, and the dentin surfaces were conditioned in subgroup-B. The samples were stored in water for 24 h at 37°C and then thermocycled. The SBS in megapascals (MPa) was determined by a shear test with 0.5 mm/min crosshead speed, and failure types were classified with modified adhesive remnant index (ARI) scores. The data were analyzed with two-way analyses of variance, Tukey's, and Chi-square tests at the 0.05 level. **Results:** The mean SBS value of subgroup-A in Group I was significantly higher than the mean values in the other groups ($P<0.05$). There were no significant differences among the SBS values in the other groups ($P>0.05$). Significant differences were found in the ARI between subgroup-A in Group I and the other groups ($P<0.001$). **Conclusions:** When used on the enamel, the self-etch systems did not have bond strengths as high as that in the conventional method. However, the self-etch systems can be used as successfully as the conventional method on dentin surfaces.

Key words
Adhesive, bonding, dentin surfaces, shear bond strength

INTRODUCTION

Buonocore's introduction of the acid-etch bonding technique in 1955 gave rise to the concept of bonding resins to enamel, which has applications in all fields of dentistry including orthodontics.[1-3] However, the routine bonding of orthodontic brackets did not take place until the 1970s.[4,5] Compared to banding, bonding brackets has some advantages, including ease of placement and removal, minimal soft tissue irritation, and hyperplastic gingivitis, and a more esthetic appearance.[6]

Self-etching primers (SEPs) were introduced[7] to simplify the bonding procedure, save chair time and materials, and reduce the disadvantages of acid-etching.

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Self-etching adhesive systems were developed for dentin bonding in conservative dentistry. In late 2000, a new SEP was developed especially for orthodontic bonding to reduce decalcification problem during orthodontic treatment.[7,8] Claims of comparable bond strengths to enamel and dentin with conventional methods of bonding suggest that these adhesives can also be used for bonding of orthodontic brackets.[9-12]

Generally, orthodontic patients have sound enamel, but occasionally patients with hypoplastic or hypomineralized enamel (such as in amelogenesis imperfect)[13] or only dentin have a demand for orthodontic treatment. It is believed that bonding composite resin by the acid-etch technique to hypoplastic or hypomineralized enamel or to dentin is more difficult than bonding it to sound enamel.[14]

There are many reports in the literature about shear bond strength (SBS) of orthodontic brackets bonded with total-etch and different self-etch systems to sound enamel and hypermineralized enamel.[10-12] However, to our knowledge, there are no reports about the SBS of orthodontic brackets bonded to dentin. Thus, the aim

of this study was to compare the SBS of orthodontic brackets bonded to enamel and dentin surfaces by using total-etching and 3 different self-etching adhesives.

MATERIALS AND METHODS

A total of 160 human mandibular incisors, extracted because of periodontal problems, were collected and stored in deionized water. The water was changed weekly to avoid bacterial growth. The criteria for tooth selection included intact buccal enamel; no pretreatment with chemical agents such as derivatives of peroxide, acid, alcohol, or any other form of bleaching; no cracks from forceps; no caries; and no restorations. The roots of the teeth were sectioned just below the cementoenamel junction with a diamond disc. The teeth were randomly and equally divided into 4 groups according to the surface-conditioning methods. In each group, the specimens were equally divided into 2 subgroups, according to the preparation (enamel and dentin). By grinding the enamel surfaces of the teeth in the second subgroup, flat dentin surfaces were obtained (subgroup-A). The buccal surfaces of the first subgroup were cleaned with coarse pumice and rubber prophylactic cups for 10 s and then rinsed and dried with an air-water syringe (subgroup-B). Each tooth was mounted horizontally in self-cure acrylic so that the crown was exposed and the labial surfaces were parallel to the applied force during the shear test.

In Group I, both the dentin and enamel groups were etched with a 37% phosphoric acid gel for 15 s. The teeth were then thoroughly rinsed with water and dried, and a layer of Transbond XT primer/sealant (3M Unitek, Monrovia, Calif) was applied to the etched area. An adhesive primer was applied to the etched surface, and the bracket was placed on the tooth and bonded with Transbond XT (3M Unitek).

In Group II, the surfaces were conditioned with Transbond Plus SEP (3M Unitek). We used a lollipop system with 2 compartments: 1 contained methacrylated phosphoric acid esters, initiators, and stabilizers and the other contained water, fluoride complex, and stabilizers. Both compartments were squeezed to activate the product, and the contents of each compartment were mixed. The resulting mix was then applied by continuously rubbing the SEP on both the enamel and dentin surfaces for 5 s, then dried with a mild air flow for 1-2 s. After that, the brackets were bonded with Transbond XT as in the total-etch group.

In Group III, the surfaces were conditioned with Clearfil Tri-S Bond Plus (Kuraray Medical, Tokyo, Japan) according to the manufacturer's instructions. The primer was applied on the enamel and dentin surfaces for 20 s; then, the surface was dried with a mild air flTr for 1-2 s. The bond was applied, distributed evenly with a mild air flow, and light-cured for 5 s. Finally, the brackets were bonded with Kurasper F (Kuraray Medical).

In Group IV, the surfaces were conditioned with AdheSE (IvoclarVivadent AG, Schaan, Liechtenstein). The primer was brushed onto the tooth surface for 30 s and gently air-dried. The bonding agent was applied to the enamel surface, gently dispersed with air, and light-cured for 10 s according to the manufacturer's instructions. The bracket was placed on the tooth and bonded with Heliosit Orthodontic (IvoclarVivadent AG).

One hundred and sixty stainless steel premolar standard edgewise brackets (790-010, Dentaurum, Pforzheim, Germany) with an average base surface area of 10 mm^2 were used in this study. In all groups, all brackets were subjected to a 400 g force, as measured with a Dontrix gauge (American Orthodontics, Sheboygan, Wisc), and excess resin was removed. The brackets were light-cured using a light-emitting diode (EliparFreeLight 2, 3M ESPE, St. Paul, Minn) for a total of 30 s, with the light beam directed for 10 s at each of the mesial, distal, and occlusal surfaces. The teeth were then stored in distilled water at 37°C for 24 h and thermocycled for 5000 cycles between 5°C and 55°C with a dwell time of 30 s at each temperature.

Debonding procedure

An occluso-gingival load was applied to produce a shear force at the enamel-adhesive interface. This was accomplished by using the flattened-end of a steel rod attached to the crosshead of a universal testing machine (Elista, TSTM 02500, Elista Corp., Istanbul, Turkey). A crosshead speed of 0.5 mm/min was used, and the maximum load required to debond the bracket was recorded. The force required to remove the brackets was measured in newtons (N), and the following formula was used to obtain the MPa value of the SBS: 1 MPa=1 N/mm^2.

Residual adhesive

After debonding, all samples and brackets were examined under ×10 magnification for the determination of the adhesive remnant index (ARI) scores. Any remaining adhesive was assessed using the ARI[15] and scored according to the ARI criteria. The ARI scale consisted of a 1-5 range: 5 indicated that no composite remained on the tooth; 4, less than 10% of the composite remained; 3, more than 10% but less than 90% of the composite remained; 2, more than 90% of the composite remained; and 1, all the composite remained on the tooth, along with the impression of the bracket base. The ARI scores were used as a comprehensive means of defining the sites of bond failure between the enamel, adhesive, and bracket base.

Statistical analysis

All statistics were performed using the Statistical Package for Social Sciences version 17.0 (SPSS, Chicago, Ill).

The Shapiro-Wilk normality test and Levene's variance homogeneity test were applied to the data. The data were found to be normally distributed, and there was homogeneity of variance among the groups. Thus, the statistical evaluation of SBS values among test groups was performed using parametric tests. Descriptive statistics were calculated for each of the groups tested. Two-way analysis of variance (ANOVA) was performed to compare the means of SBS values. *Post hoc* multiple comparisons were done with the Tukey Honestly Significance Difference (HSD) test. For the ARI scores, the Chi-square test was used to identify any significant differences among the groups. The statistical significance level was set at $P<0.05$.

RESULTS

The results of two-way ANOVA indicated that the difference between the groups ($F=3.471$, $P=0.036$) was significant, that the difference between the subgroups ($F=1.019$, $P=0.186$) was not significant, and that there was no interaction between the groups and the subgroups ($F=0.086$, $P=0.616$) [Table 1]. The descriptive statistics and comparisons of the 8 groups in this study are shown in Table 2. The mean SBS value for Group I in the enamel subgroup was significantly higher than those for the other groups in both subgroups. However, there were no significant differences in other groups in both subgroups.

ARI was used to assess the amount of resin left on the enamel surfaces after debonding. The ARI scores for the various groups tested are shown in Table 3. The Chi-square comparisons (75.937) of the ARI scores among all groups indicated that the groups were significantly different ($P<0.001$). In the enamel subgroup of Group I, there was a higher frequency of ARI scores of 1 through 3, indicating cohesive failures in the resin. In the other groups, the failures were mostly adhesive at the resin-enamel interface, and the scores were a mix of 2 through 5.

Table 1: Results of two-way ANOVA

Source	SS	*df*	MS	*F*	*P*
Adhesive	214.346	1	214.346	3.471	0.036
Surface	164.624	2	82.312	1.019	0.186
Intercept	2145.302	1	2145.302	46.041	0.006
Adhesive×Surface	24.264	2	12.132	0.086	0.616

SS – Some of squares; *df* – Degrees of freedom; MS – Mean square; ANOVA – Analysis of variance

Table 2: The descriptive statistics and statistical comparisons of the SBS values

Groups	*n*	Mean	SD	Min-Max	Post hoc Tukey*
Group I					
Enamel	20	18.27	3.58	13.56-23.61	A
Dentin	20	10.12	3.82	7.32-14.08	B
Group II					
Enamel	20	9.46	2.54	6.75-13.33	B
Dentin	20	10.54	2.81	6.92-15.81	B
Group III					
Enamel	20	10.38	2.45	6.14-14.68	B
Dentin	20	10.93	2.72	6.08-15.24	B
Group IV					
Enamel	20	9.68	3.14	6.23-15.49	B
Dentin	20	10.64	3.22	6.31-15.73	B

*$P<0.05$; SBS – Shear bond strengths

Table 3: Frequency of distributions and statistical comparisons of the ARI scores

Groups	ARI scores					Sign
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Group I						
Enamel	8 (40)	5 (25)	5 (25)	2 (10)	0	A
Dentin	0	4 (20)	5 (25)	5 (25)	6 (30)	B
Group II						
Enamel	0	2 (10)	3 (15)	7 (35)	8 (40)	B
Dentin	0	3 (15)	5 (25)	5 (25)	7 (35)	B
Group III						
Enamel	0	2 (10)	2 (10)	6 (30)	10 (50)	B
Dentin	0	4 (20)	5 (25)	5 (25)	6 (30)	B
Group IV						
Enamel	0	1 (5)	5 (25)	4 (20)	10 (50)	B
Dentin	0	4 (20)	5 (25)	4 (20)	7 (35)	B

Chi-square 75.937, $P<0.001$; ARI – Adhesive remnant index

DISCUSSION

This study was designed to determine which etching systems had acceptable SBSs when used to bond orthodontic brackets to enamel and dentin surfaces. The results of this study show that total etching remains a reliable system when used on enamel surfaces. In addition, self-etching systems can be used successfully on dentin surfaces, as can the total-etch system. The highest mean SBS of orthodontic brackets was obtained using the total-etch system on enamel surfaces. The mean SBS values of self-etch systems on both surfaces and the total-etch system on dentin surfaces showed no significant differences.

Generally, conventional acid-etch bonding systems include three different agents: An enamel etchant, a primer solution, and, in orthodontics, an adhesive resin for bonding brackets.[16,17] Self-etching systems were introduced to combine the functions of the primer and adhesive components and to reduce the steps required in the total-etch system. These new systems have reduced chair time, therefore improving the comfort of patients and clinicians.[18]

Self-etching and total-etching systems were used according to the manufacturer's instructions. The best adhesive results can be achieved by using the same

manufacturer's bonding system and composite.[19] Therefore, the same manufacturer's composites and bonding systems were used.

There is no consensus that self-etch systems can be used as successfully as the total-etch system for bonding orthodontic brackets. Some studies have suggested that self-etch systems can be used as safely as the total-etch system.[16,20] while others have shown that some self-etch systems have SBS values higher than those minimally required for orthodontic treatment, but lower SBS values than those of the total-etch system.[17,21,22] With respect to bonding to enamel, the results of this study are in accordance with those of the second group.

A survey of the literature failed to discover any studies that compared SBS values of orthodontic brackets bonded to human enamel and to dentin. However, many studies have been published about dentin and enamel bond strengths in operative dentistry.[23-25] The results of our study are in agreement with reports that indicate that self-etching adhesives still do not perform as well as total-etch adhesives on enamel, but on the other hand, perform relatively well on dentin.

It has been suggested that the minimum bond strength value adequate for most clinical orthodontic needs and routine clinical use is 5.9-7.8 MPa.[26] Bowen and Rodrigues[27] and Retief[28] suggested that the maximum bond strength should be less than 14 MPa, which is the breaking strength of enamel. In our study, the SBS values were more than sufficient for clinical orthodontic needs. But the mean SBS value of the total-etch system in the enamel subgroup was higher than the breaking strength of the enamel, while the others were lower than it. The results of self-etching systems compared with the conventional total-etch system were quite satisfactory for orthodontic purposes. However, clinical conditions and *in vitro* conditions are different. Since this was an *in vitro* study, the conditions did not completely duplicate the rigors of the oral environment.

The results of the ARI score comparisons in this study indicate that there were significant differences among the eight groups tested. When comparing the ARI scores of the groups, only the enamel subgroup of the total-etch system differed from the other groups. The ARI scores were predominantly 1-3 in the total-etch enamel subgroup and 2-5 in the other groups. The mode of failure was at the resin-enamel interface with the total-etch system, resulting in an increase in the risk of enamel fracture. However, the other groups did not show this risk. This is a desirable result, because of the reduced risk of fracturing or damaging the teeth during debonding procedures. The degree of penetration by adhesive to the etched enamel is less in the self-etch systems than in the total-etch system. The greater penetration of the adhesive could cause greater risk of damage to the tooth hard tissue.[29]

Although it is impossible to create laboratory conditions that fully represent the oral environment, five thousand thermocycles between 5°C and 55°C were made in this study. This equates to a number of years of intraoral thermocycling, exceeding the average orthodontic treatment term.[30] Thermally stressing the adhesive-joint interface was the aim of the thermocycling procedure. It is true that *in vitro* bond-strength testing is not fully representative of intraoral conditions. However, it can give an idea of the clinical performance of the various systems tested.

From the clinical standpoint, it may be advantageous to use self-etch systems on enamel surfaces because they reduce clinical chair time and provide clinically acceptable SBS values for bonding orthodontic brackets. Andusing, self-etch systems is desirable for bonding orthodontic brackets to dentin because they offer reduced clinical chair time, improved adhesion, and reduced risk of damage to hard tissue.

CONCLUSIONS

The following conclusions were drawn within the limitations of this *in vitro* study:

- SBS values of all groups were higher than the clinically acceptable bond strength value (5.9-7.8 MPa)
- The 3 self-etching systems had favorable mean values of SBS, but orthodontic brackets can be more successfully bonded to enamel surfaces by the conventional total-etch system
- The 3 self-etching systems can be used successfully, as can the conventional total-etch system, on dentin surfaces.

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