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Comparison of shear bond strength and enamel surface changing between the two-step etching and primer and self-etch primer methods in rebonding of orthodontic brackets: An *in vitro* study

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ABSTRACT

Background: The aim of this study was to compare shear bond strength (SBS) and enamel surface changing of two methods of bonding in rebonding of orthodontic brackets.

Materials and Methods: In this *in vitro* study, 30 human premolars were randomly classified into three equal groups. Two bonding systems were applied. At first bonding, Group 1 and 2 were bonded by conventional etching and primer technique (CEP) and Group 3 by self-etching primer (SEP). Thermocycling for 5000 cycles was done. Then, 30 brackets were debonded and SBS and Adhesive remnant index (ARI) were evaluated. One sample was selected from each group, for SEM, 30 new brackets were used for rebonding. Group 1 was bonded by CEP method and Group 2 and 3 were bonded by SEP method. Thermocycling, SBS, ARI, and scanning electron microscope (SEM) were done in the same protocol of the first bonding. One-way ANOVA, two-sample *t*-test, and Mann–Whitney U-test were used for statistical analysis. $P < 0.05$ was considered statistically significant.

Results: The mean SBS values were not significantly different between the three groups in the first bonding and rebonding stages ($P = 0.22$ and 0.24). Further, there was no significant difference between the first bonding and rebonding in SBS values of Groups 1, 2 and 3 ($P = 0.44$, $P = 0.60$, and $P = 0.56$). SEM examination showed obvious differences in the enamel surface between CEP and SEP samples in both first bonding and rebonding.

Conclusion: With regard to the advantages of SEP methods, it seems this method can be properly used for rebonding of orthodontic brackets.

Key Words: Adhesive, bond strength, scanning electron microscope, self-etch primer

INTRODUCTION

Dental bonding was introduced by Bowen following the pioneering work of Buonocore *et al*. on enamel preparation techniques.[1,2] These principles were applied to orthodontics afterward and revolutionized appliances physically and cosmetically, as a result of which multibanding systems became outdated and bonded appliances came to being.[3] Further advancement has been made into the realm of bonding with a focus on streamlining the process, boosting the performance in a moist environment, and improving resistance to demineralization.[4] Two

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major techniques are used for direct bonding of brackets: The conventional two-stage etching and primer method (CEP) and the self-etching primer method (SEP).[5,6] The benefits suggested for SEP consist of reduced chair-side time, although this is tempered by the need for sound pumicing before bonding procedures to reduce the risk of failure;[7] reduced sensitivity to moisture; and reduced inventory requirements.[8] Differences between these two techniques in the initial bonding of brackets have been investigated comprehensively.[8-10] In spite of remarkable progress, the bond failure of brackets is commonplace and unfavorable during orthodontic treatment.[11-13] This failure is usually caused by applying excessive masticatory force by the patient, inappropriate bonding method, or dental contamination during bonding.[14,15] Sometimes, the practitioner debonds a bracket in order to relocate it more appropriately to gain a better result.[16] The new brackets are mostly rebonded like the first bonding using the same protocol.[13] Conditioning the enamel surface with acid and applying the primer afterward are traditional methods for direct bonding of orthodontic attachments.[17] This technique may cause side effects such as unrestricted enamel loss by inexorable over-range etching[18] and enamel surface vulnerable changes induced by acid-etching.[19,20] However, etching in the first bonding causes enamel alteration and etching during the second bonding (rebonding) may further induce enamel loss.[13] Montasser *et al*. reported that etching-induced shallow depressions and pits were still presented on the enamel surface after debonding and removal of all-visible adhesive. So far, the majority of published data have merely focused on the effect of acid etching on the first bonding of brackets. Few studies, however, have been done on the rebonding of brackets using different adhesive systems[21,22] or on the optimal procedure for rebonding of brackets.[13,23] Because of acid etching, enamel damage from the first bonding and several advantages of self-etch primers as well as lack of studies comparing these two methods in bracket rebonding, this study was conducted to compare the results of brackets rebonding by CEP and SEP methods in shear bond strength (SBS) and enamel alteration.

MATERIALS AND METHODS

This study was approved by reserch and ethics committe of Isfahan University of Medical Sciences, Isfahan, Iran (No. 396168). This *in vitro* experimental study was performed on 30 human premolars that were freshly extracted for the orthodontic purposes. They were kept in an aqueous solution of thymol (0.1% weight/volume) that made with 0.1 grs thymol in 100 ml water by examiner. The root of each tooth was mounted on a block of self-curing acrylic (AcroPars, Marlic Medical Co., Tehran, Iran), with vertical long axis. Each tooth was allocated a unique number, and the teeth were randomly classified into three equal groups. A total of 60 stainless steel Roth brackets (0.022 × 0.028 slot) for premolars were used (Ortho Organizers Inc., California, USA). Two bonding systems were applied:

1. CEP system: Acid (3M™ ESPE™ Etchants) and nonacidic primer (Transbond XT Primer); adhesive resin (Transbond XT Light Cure Adhesive Paste)
2. SEP system: Acidic primer (Transbond plus SEP) and adhesive resin (Transbond XT Light Cure Adhesive Paste).

All the above-mentioned materials were from 3M Unitek (Monrovia, California, US). All of the bonding and rebonding and the following procedures were carried out by the same operator. At the first bonding, Groups 1 and 2, including 20 teeth, were bonded by CEP technique according to the instructions provided by the manufacturer. In brief, the enamel surface was etched with 37% phosphoric acid for 30 s. It was then rinsed and primed with nonacidic primer. Next, adhesive paste was applied on the brackets and the brackets were polymerized for 20 s by a visible light-curing unit (3M Unitek Ortholux LED Curing Light, US) with an output power of 600 mW/cm^2. Group 3, including 10 teeth, was bonded by SEP technique. The enamel was etched and primed with acidic primer, which was followed by application of adhesive paste. Two minutes after bonding the brackets, the specimens were kept in deionized water (37°C) for 24 h in a digital incubator (Behdad, Tehran, Iran), each group being kept in a separate container before the following step. After that, the brackets were thermocycled by Thermocycling Machine (Delta Tpo2, Nemo, Mashhad, Iran) for 5000 cycles at 5°C–55°C, with the dwell time of 30 s and transfer time of 10 s between baths, to simulate the heat and humidity of the oral cavity. Then, the 30 brackets were debonded by a universal testing machine using a standard protocol. The SBS of each sample was then evaluated. The shear bond test was performed by a chisel edge which was mounted on the crosshead of a Universal Testing Machine (K–

21046, Walter + Bai AG, Lohningen, Switzerland). The edge was targeted at the bracket–enamel interface with a crosshead speed of 1 mm/min. Next, the debonding forces were recorded for each specimen in Newtons and were then converted to Megapascals. SBS was computed through dividing this force by the bracket base area. The shear bond test was carried out by a technician who was blind to the preparation procedures that were carried out for the groups. Then, the enamel surfaces were tested by a stereomicroscope at magnification of ×10, and the adhesive remnant index (ARI) was measured based on the criteria established by Artun and Bergland,[24] that is, 0 = no adhesive left on the tooth, 1 = less than half of the adhesive left on the tooth, 2 = more than half of the adhesive left on the tooth, and 3 = all the adhesive left on the tooth, immediately after the assessment of the SBS of debonding. To scanning electron microscope (SEM) examination, one sample with no remnant was randomly selected from each group. The crowns of the three groups were sectioned in mesiodistal direction by a diamond separating disc, which left only a thin layer of the underlying dentin. They were polished by pumice and rubber prophylactic cups for 10 s, were cleaned in distilled water with ultrasonic agitation for 30 min, and were slowly air-dried. They were affixed to SEM stubs, covered with gold, and tested on Jeol JSM-6510A SEM (Tokyo, Japan) operating at 10 kV. To prepare the samples for rebonding, all visible residual adhesive was carefully removed by a low-speed hand-piece with a tungsten bur under light pressure and sufficient air cooling with no water spray. The removal of composite was regarded to be complete when the tooth surface appeared smooth and free of composite to the naked eye under an operatory lamp. A total of 30 brand new brackets were used, and the teeth were assessed by one of the two rebonding techniques illustrated in Figure 1. Group 1: 37% phosphoric acid + nonacidic primer + adhesive and Groups 2 and 3: Self-etch acidic primer + adhesive. All the rebonded samples were then immersed in deionized water, each group being placed in a separate container. They were then placed in a humidor at 37°C for 24 h in a digital incubator (Behdad, Tehran, Iran). Thermocycling, SBS testing, ARI, and SEM were done in the same protocol of the first bonding as mentioned before. Descriptive statistics, including mean, standard deviation, and maximum and minimum SBS values were calculated for each group. One-way ANOVA test and two-sample *t*-test were applied to detect the differences between groups in SBS. Mann-Whitney U-test was used to evaluate the ARI scores. $P < 0.05$ was considered statistically significant.

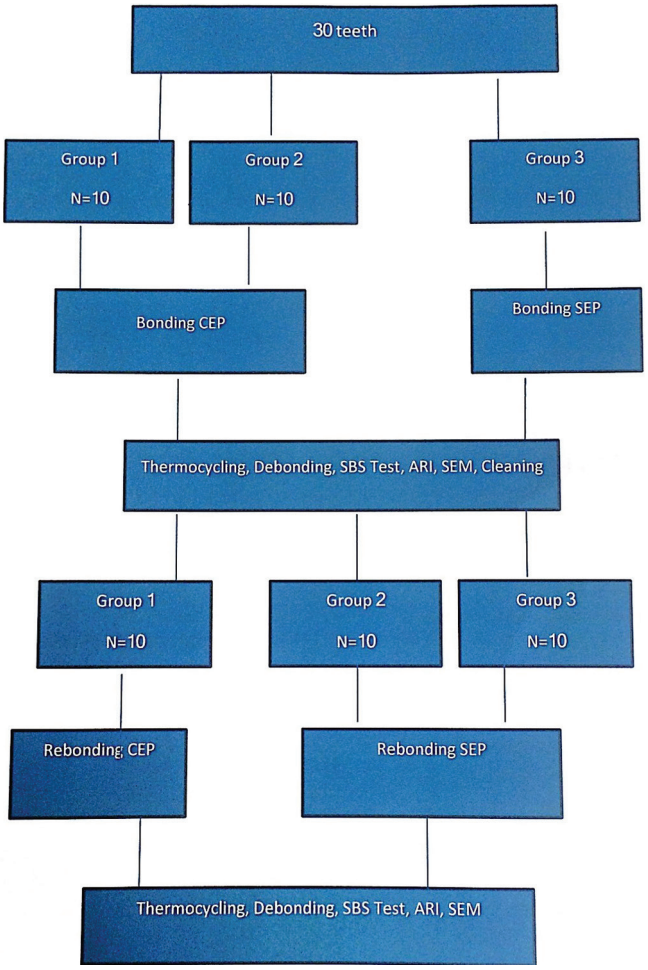

Figure 1: The diagram shows sample preparation protocol. Note: CEP: Conventional etching and primer, SEP: Self-etching primer, SBS: Shear bond strength, ARI: Adhesive Remnant Index.

RESULTS

Descriptive statistics about SBS test for all groups are presented in Table 1. The results of one-way ANOVA test showed that the mean SBS values were not significantly different between the three groups in the first bonding ($P = 0.22$) [Table 1]. Furthermore, in rebonding stage, the mean SBS values were not significantly different between the three groups ($P = 0.24$) [Table 1]. Further, the findings of *t*-test showed no significant difference between the first bonding and rebonding in SBS values of Groups 1, 2, and 3 ($P = 0.44$, $P = 0.60$, and $P = 0.56$, respectively). Descriptive statistics of ARI score for all groups are presented in Table 2.

Table 1: Descriptive statistics for the shear bond strength test for Groups 1, 2, and 3 in the first bonding and rebonding and their comparison with one-way ANOVA test

Stage	Group	*n*	Mean (MPa)	SD	SE	95% CI for mean		Minimum	Maximum	*P*
						Lower bound	Upper bound			
First bonding	1	10	23.76	13.06	3.93	14.98	32.53	5.04	43.52	0.22
	2	10	26.23	12.17	3.85	17.52	34.94	6.64	45.35	
	3	10	17.94	7.47	2.25	12.92	22.96	9.08	29.37	
Rebonding	1	10	28.48	14.29	4.52	18.25	38.71	11.56	56.42	0.24
	2	10	29.67	15.99	5.33	17.37	41.96	6.80	61.04	
	3	10	20.13	9.33	2.95	13.45	26.81	4.02	32.56	

In first bonding, Groups 1 and 2 were bonded by conventional etching and primer and Group 3 was bonded by self-etching primer. In rebonding, Group 1 was bonded by conventional etching and primer and Groups 2 and 3 were bonded by self-etching primer. SD: Standard deviation; SE: Standard error; CI: Confidence interval

Table 2: Frequency distribution of Adhesive Remnant Index

Stage	Group	ARI score			
		0	1	2	3
First bonding	1[a]	1	0	7	2
	2[a]	1	2	5	2
	3[b]	2	7	1	0
Rebonding	1[a]	1	0	8	1
	2[a,b]	1	7	0	2
	3[b]	1	9	0	0

Different lower letters show significant difference between groups. In the first bonding, Groups 1 and 2 were bonded by conventional etching and primer and Group 3 was bonded using self-etching primer. In rebonding, Group 1 was bonded by conventional etching and primer and Groups 2 and 3 were bonded by self-etching primer. ARI: Adhesive Remnant Index

Mann–Whitney test showed a significant difference in ARI score between Groups 1 and 3 as well as Groups 2 and 3 in the first bonding (P = 0.001 and P = 0.02, respectively). In rebonding stage, ARI score was significantly different between Group 1 and 3 (P = 0.001). Mann–Whitney test showed no significant difference between the first bonding and rebonding in the ARI score of Groups 1, 2, and 3 (P = 0.67, P = 0.21, and P = 0.99), respectively. Analysis of SEM showed obvious differences in the size and depth of the anomalies on the enamel surface between CEP and SEP samples in both first bonding and rebonding [Figures 2 and 3].

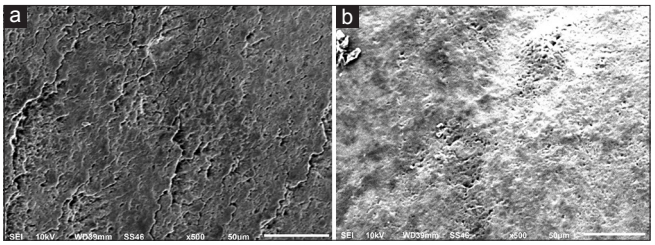

Figure 2: Scanning electron microscope scans show enamel surface of two different methods of bracket bonding in the first bonding: (a) Conventional etching and primer, (b) Self-etching primer.

DISCUSSION

There should be sufficient optimal orthodontic bond strength to retain the brackets for a favorable treatment duration.[13,25] Higher SBS may help to eliminate the unexpected bond failure of brackets during orthodontic therapy, but the risk of enamel fracture and patient discomfort may increase during the removal of brackets.[13,25] In this study, two methods of bracket bonding (SEP and CEP) were compared in the first bonding and rebonding. Although SBS mean of CEP groups was more than SEP ones, there was no significant difference between SEP and CEP in SBS in both first bonding and rebonding (P = 0.22 and P = 0.24, respectively). These findings were in agreement with the results of Fleming *et al*., Zhang *et al*., and Schauseil *et al*. studies that say SBS of conventional system was notably similar to SEP and resin system.[8,13,26] Clinically, sufficient bond strengths for metal brackets to enamel have been suggested to be between 5.9 and 8 MPa.[27] In this study, the mean SBS values of CEP and SEP methods in both first bonding and rebonding were more than this range and were not significantly different with each other. Also in this study, the mean SBS values in the first bonding and rebonding were not significantly different, which is consistent with the findings of Montasser *et al*. and Nicolás *et al*. This indicates that SBS values in the repeated bonding and rebonding were not significantly different.[16,21,22]

In this study, ARI index was assessed to show the adhesive remnant on the teeth after debonding. In both first bonding and rebonding, ARI index was significantly different between CEP and SEP groups. ARI scores showed that the SEP samples had a higher number of score 1. It means that less than half of the

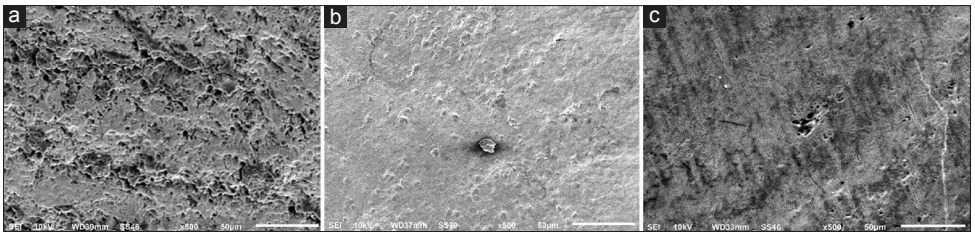

Figure 3: Scanning electron microscope scans show enamel surface of two different methods of bracket bonding in the rebonding: (a) Conventional etching and primer, (b and c) Self-etching primer.

adhesive was left on the teeth, but in CEP samples, more adhesive remnants were left. These results are in agreement with those of Montasser *et al*., Zeppieri *et al*., and Oliver studies, indicating that high ARI values observed by conventional phosphoric etch systems are associated with the improved mechanical union between the composite and enamel.[21,28-30] Self-etching system shift from more adhesive on the enamel to bracket.[26,31] Lower adhesive remnant on the teeth in SEP method may save the time of adhesive removal from the teeth after debonding and reduces the invasive process of adhesive removal from enamel.[32] Our results on ARI scores are in contrast with those of Zhang *et al*., indicating no significant difference between SEP and CEP methods in rebonding.[13] In this study, Group 2 was bonded by CEP method in the first bonding and by SEP method in the rebonding stage. ARI scores of this group in rebonding stage were not significantly different neither with Group 1 nor with Group 3. Enamel surface changing in the first bonding may be responsible for the ARI scores of Group 2 that are between Groups 1 and 3. In addition, our findings showed that ARI scores were not significantly different between the first bonding and rebonding, which is in agreement with the results of Montasser *et al*.[21]

Further, in this study, enamel surface changing was observed in SEM examination. The enamel treated by CEP method caused more enamel damage than the one treated by SEP method in both first bonding and rebonding stages, which was in line with the results of Ogaard *et al*. and Hosein *et al*. studies which indicated self-etching adhesive system reduced the amount of enamel loss[33,34] and had more conservative etch pattern.[35] Orthodontic brackets are routinely bonded by CEP methods. When a bracket has been debonded, the clinician can bond the new bracket by SEP or CEP methods. Group 2 in this study was selected to show the results of first bonding by CEP method and rebonding by SEP method. Although the SBS values of this group were approximate to Group 1 (CEP) but were not significantly different with those group 1 and 3; Etching from first bonding and its remaining enamel changes in rebonding stage may be responsible for these results. Moreover, the mean SBS values of the first bonding and rebonding of this group were not different. Considering the results of this study and other reasons mentioned for favorable SBS values, decreased chair-side time for bonding and adhesive removal process, decreased technical sensitivity, and lower enamel damage, it seems that SEP method can be a suitable option for rebonding of orthodontic brackets. In this study, thermocycling was used to simulate oral moisture and temperature. However, future clinical studies and with more samples are suggested to compare SEP and CEP methods in rebonding of orthodontic brackets.

CONCLUSION

In this study, the mean SBS values of CEP and SEP methods were not significantly different. ARI scores were different between the two methods, and SEP method showed lower enamel damage in SEM analysis, but SEM assumption is only based on one sample in each group and needs further investigations. With regard to the mentioned advantages of SEP methods, it seems this method can be properly used for rebonding of orthodontic brackets.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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