Efficacy of delay in self–etching primer application time on shear bond strength of stainless steel brackets

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Abstract:

This study assessed the effects of delay in application time of self–etching primer (3M Unitek, Monrovia, California, USA) on shear bonding strength of stainless steel brackets. A sample of 42 extracted upper first premolars included in this work. They were divided into 6 groups, each of 7 teeth. In the first group, the self–etching primer is applied on the middle third of the buccal surface of teeth for 3 seconds according to manufacturer's instruction, followed by gentle stream of air, then brackets positioned and the adhesive polymerized by light cure system. In groups 2, 3, 4, 5 and 6, the self–etching primer was delayed in tooth surface for 2, 5, 10, 15 and 20 minutes, respectively; then the same procedures as in the first group were carried out. Shear bond strength was measured in megapascal (MPa). The results indicated significant increase of bonding force accompanied to the increase in delay of application time ($p< 0.05$), as the mean forces were 8.17, 8.26, 8.34, 8.48 and 8.61 MPa, for the first group with 3 seconds, group 2 with 2 minutes, group 3 with 5 minutes, group 4 with 10 minutes, group 5 with 15 minutes, but it began to decrease at the sixth group with 20 minutes as the mean value was 8.27 MPa. Beside that, there is positive significant correlation between the bonding strength and the delay in application time with $r = 0.373$ at $p< 0.05$. The adhesive remnant index presented a decrease in failure rate at the adhesive / tooth interface with the increase of shear bond strength. Most of the readings fall in score 1 but for the fifth group (15 minutes) they were at score 2, and in the sixth group (20 minutes), here the failure rate was returned back to the score 1 again.

From this in vitro study, it can be concluded that the delay of self–etching primer application time up to 15 minutes has significant effects on bonding strength but this increase to be within the normal limited orthodontic force. So, this delay in time appeared to be very important to the clinician to use it in the other bracket bonding procedures.

Key Words:

Self–etching primer, orthodontic adhesive, shear bond strength, stainless steel brackets.

Introduction:

Many efforts have been taken to reduce the number of steps involved with bonding. The researchers and manufacturers developed simplified systems by combining the etchant and primer or the primer and adhesive (1).These so–called fifth–generation bonding systems, which have demonstrated similar restorative bond strength in vitro and in vivo (2, 3).To

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simplify things further, all–inclusive bonding systems have been developed that incorporate etchant, primer and adhesive in 1 bottle, commonly known in restorative dentistry as the sixth–generation of dentin bonding agents(1). The active ingredient in self–etching primer is the methacrylated phosphoric acid ester. Phosphoric acid and methacrylate group are combined in a molecule that etches and primes simultaneously (4). One of the advantages of it is that the primer penetrates into the entire depth of the etch, ensuring an excellent mechanical interlock, then the phosphate group dissolves the calcium and removes it from the hydroxyapatite rather than being rinsed away. The calcium forms complex with the phosphate group and is incorporated into network; in this manner the acid is neutralized (4).

Several studies (5–7) were carried out to assess the brackets bonding strength that attached by self–etching primer adhesives in comparison with the conventional one (which used phosphoric acid and primer separately). Many of them(8, 9) were recorded that self–etching primer adhesives gave lower but acceptable bonding strength, but their claims of significantly reduced application times might have been premature. However, there is unresolved question about the manipulation of the material. Some manufacturer's instructions state that bonding can be delayed for up to 2 minutes after primer application if there is no salivary contamination, but clinically it is impossible that dentition from premolar to premolar could be bonded in only 2 minutes of time. This is not discussed in the current literatures, except Arnold et al., (10) who recorded that 10 minute delay in bonding after application of the self–etching primer might not be deleterious to adhesion in vitro.

The question, then, must the manufacturer's time limit be followed restrictedly in order to avoid any unfavorable bonding results? And does the 10 minutes of time is a red line can not overcome?

This study is undertaken to find that the delay of up to manufacturer's instruction time after application of self–etching primer and before bonding have any significant effect on shear bond strength of stainless steel brackets to enamel.

Materials and methods:

In this study, 42 freshly extracted human upper first premolars were collected and stored in solution of 70% ethyl alcohol. The criteria of tooth selection included intact buccal enamel with no cracks caused by extraction, no caries or hypocalcification, and teeth not subjected to any pre–treatment agents. Before bonding each tooth was cleaned from any tissue remnants and embedded in plastic ring. The parallelism and uprighting position of each tooth was oriented by analyzing rod of the dental surveyor (Quayle Dental Mfg. Co., England) after and before cold–cure acrylic resin pouring around the tooth (Medicus cold cure, DMP Ltd., E.U.), so as to get a correct parallelism with shearing force. Each tooth was polished with non–fluoridated pumice and rubber prophylactic cup (JTC–Full Dent S.A., Swiss) for 10 seconds (7, 8, 10) by conventional handpiece (Belmont PNEU–MARI), then washed and dried by air and water stream for 30 seconds. One operator bonded 42 maxillary first premolar brackets with 0.022" slots, 0 torque and angulation, double wing, mesh–back with basal surface area of 32.58 cm2 (Ultramintum Dentaurum Co., Germany). Before bonding they were randomly divided into 6 groups. They were received the same protocol

as in group 1 (control group) with a difference in time at which the self–etching primer was left (delay) on the buccal surface of each tooth at each group.

Seven teeth at each of the 6 groups were received the self–etching primer (3M Unitek Co., Menrovia, California) but for 6 different application times. In the first group (control group) the middle third of buccal surface of each tooth received directly and only drop of self–etching primer. The material was rubbed on tooth surface and left for 3 seconds according to manufacturer's instructions. A gentle air burst is applied, then the adhesive (3M Unitek Co., Menrovia, California) was applied on bracket base and the bracket was positioned and pressed firmly on tooth surface gently remove excess from around bracket base without disturbing bracket. Each side of bracket (mesial, distal, occlusal and gingival) was light cured by light cure unit (Quayle Dental Co., England) for 10 seconds per side according to manufacturer's instructions. Meanwhile, in group 2 the delay in application time was 2 minutes; in group 3 was 5 minutes; group 4 was 10 minutes; group 5 was 15 minutes and in the last group the delay in application time of self–etching primer was 20 minutes.

To achieve reproducible conditions, each bracket was subjected to 300 gm of compressive force for 10 seconds (7, 10) by using dental surveyor arm. The load was placed over the arm and the rod was positioned to be perpendicular to the bracket slot. All teeth were stored in distilled water at 37° for 48 hours before debonding procedures (7, 10) .

The sample then tested in shear mode on a universal testing machine (Electric Unconfined Compression Apparatus, Soil Test Co.). The specimen was secured in a position that the bonded bracket base was parallel to the shear force which applied in occluso–gingival direction by a steel rod with flatted end. The rod was parallel to the middle third of the buccal surface of tooth and crush at interface between bracket and tooth. The cross head speed was 1 mm/min (10).The maximum load necessary to initiate bracket fracture was recorded in Newton and then converted into megapascal.

After bond failure, the bracket bases and the enamel surfaces were examined under an optical microscope at 10× magnification. The adhesive remnant index (ARI) was used to assess the amount of adhesive left on the enamel surface (11).

The primary investigator scored the teeth as follows:

0= no adhesive remaining on the tooth in the bonding area.

1= less than half of adhesive remaining on the tooth in the bonding area.

2= more than half of adhesive remaining on the tooth in the bonding area.

3= all adhesive remaining on the tooth, with distinct impression of the bracket mesh.

ARI scores were used as a more complex method of defining bond failure site among the enamel, adhesive and the bracket base.

Results:

The descriptive statistics for shear bonding strength are presented in Table (1). Here, the numerical values are increased gradually by increasing of the application time of the self–etching primer, until group 6 as there was a decrease in bonding strength in spite of the increasing in the application time which was 20 minutes at this group. The largest shear bonding strength was 8.60 MPa which related to group 5 (15 minutes). This

change in shear bonding strength appeared to be significant one, and the One–Way Analysis of Variance (ANOVA) give F ratio = 10.695 at $p < 0.001$.

Table (1): Descriptive analysis of shear bonding strength values in MPa according to the delay in application time of self–etching primer

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Delay in Application Time	3 Seconds	2 Minutes	5 Minutes	10 Minutes	15 Minutes	20 Minutes
Mean	8.17	8.26	8.34	8.48	8.61	8.27
± SD	0.18	0.13	0.12	0.023	0.057	0.04

Sample number = 7 for each group; SD: Standard deviation.

The Duncan's test was carried out to explore deeply the results of the ANOVA test which indicated that groups 4 and 5 carried the main responsibility about the significant results as shown in Table 2.

Table (2): Results of Duncan's test among the study groups

Delay in Application Time	Mean Value	Duncan's Test*
3 Seconds	8.17	C
2 Minutes	8.26	BC
20 Minutes	8.27	BC
5 Minutes	8.34	B
10 Minutes	8.48	A
15 Minutes	8.61	A

*Different letters mean significant difference at $p < 0.05$.

In this study, a significant positive correlation was found between the shear bonding strength and the application time, $r = 0.373$ at $p < 0.05$. The diagram of correlation is in Figure (1).

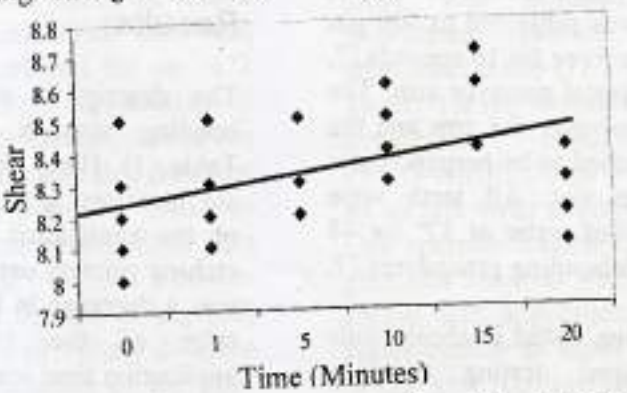

Fig. (1): Scatter diagram of shear bonding strength and its delay in application time

The frequency distribution of ARI scores is illustrated by a bar diagram at Figure (2). We noticed that the samples of groups 1, 2, 3 and 6 are concentrated at score 1 where a less than half of the adhesive are remaining on tooth surface, while in group 4 the sample is distributed between scores 1 and 2. Meanwhile, group 5 teeth are located in score 2 in highly manner; only 2 samples of group 1 fall in score 0, and 1 sample of group 5 at score 3.

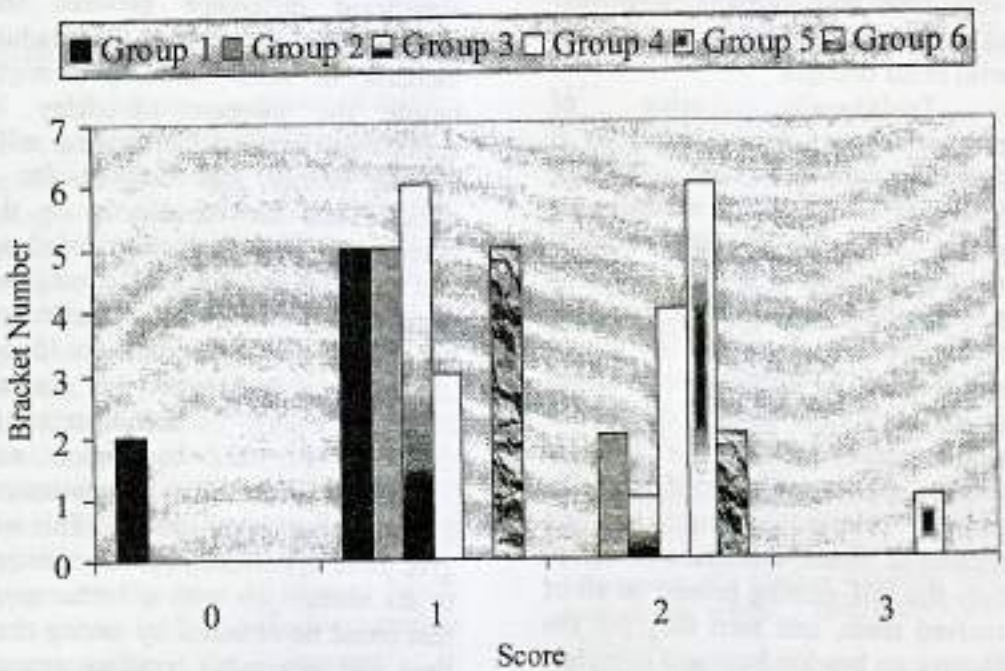

Fig. (2): Frequency distribution of adhesive remnant index score for the study groups

The mean values and percentage distribution according to their scoring and groups are presented in Table (3). Again, the ANOVA among means of ARI of the group showed significant difference with F ratio = 5.238 at $p < 0.05$.

Table (3): Percentages and mean values for the adhesive remnant index according to the groups and delay in application time of the self–etching primer

Group	Application Time	Adhesive Remnant Index Scores				Mean	± SD
		0	1	2	3		
1	3 Seconds	28.57 %	71.42 %	0 %	0 %	0.71	0.50
2	2 Minutes	0 %	71.42 %	28.57 %	0 %	1.28	0.50
3	5 Minutes	0 %	85.71 %	14.28 %	0 %	1.42	0.73
4	10 Minutes	0 %	42.85 %	57.14 %	0 %	1.57	0.54
5	15 Minutes	0 %	0 %	85.71 %	14.28 %	2.14	0.38
6	20 Minutes	0 %	71.42 %	28.57 %	0 %	1.28	0.50

SD: Standard deviation.

Discussion:

The direct bonding of orthodontic brackets has revolutionized and advanced the clinical practice of orthodontics. However, there is a need to improve bonding procedures by saving time and minimizing enamel loss without jeopardizing a clinically useful bond strength [6].

Traditionally, using of phosphoric acid followed by primer is essential part of the bonding procedures of composite adhesive. A thought to simplify the clinical handling of adhesive system was done by combining the etchant and the primer into 1 application. The use of these systems for orthodontic purposes has not been fully understood [12].The manufacturers indicated a specific delay in application time of the self-etching primer during bonding procedures. Some clinicians prefer to apply the self-etching primer on all of involved teeth, and then they put the adhesive on bracket base and complete the other procedure, for each bracket, one by one. By painting the primer in all of the teeth at same time and leaving it to finish other step on the other bracket we will preserve chair time. The second point of view is that the teeth with high fluoride concentration in some populations are considered to be more resistant to self-etching and need longer application time.[13] Also, when the self-etching adhesive were bonded to unground, intact enamel the bonding strength values considerably lower than in the ground enamel[13,14]. In orthodontics, most of bonding procedures are performed on intact unground enamel.

In this work, there is an apparent tendency for increasing shear bond strength by increasing the delay in application time of the self-etching primer. This change appears to be a statistically significant, but the recording mean values are within numerical that required to withstand normal orthodontic forces which are thought to be between 8-9 MPa [15]. These results disagree with the available literatures[10], because the available one indicated a non-significant difference between the study groups in spite of the gradual increase in shear bonding strength beside the increase of delay in application time as the applied self-etching primer was delayed for 2 minutes and for 10 minutes on the other group until the curing carried out and gave 8.4 and 9.8 MPa shear bond strength, but in our work we extended the delay in application time for 15 and 20 minutes and here we noticed different results. in accompanied to that, a significant correlation was found between delay in application time and shear bond strength. This will give more opportunity for the clinician to do his/her job with a better result that could be obtained by saving chair time and increasing bonding strength within the normal limits.

Usually, the laboratory assessment of bond strength can not predict clinical performance but, rather, is a valuable screening tool. Most of bonding strength studies, including the present one, uses the bracket base area in calculating stress. This will not allow interpretation across other studies because brackets differ in design, size and base morphology [16]. These limitations are inherent in all laboratory studies concerning bonding strength of brackets, but the results still serve as valuable resources of information.

The ARI indicated that with the longer delay time the smaller adhesive failure rate, until the 20 minutes group the index started to give different numerical change. Here, the adhesive failure mode begins to increase. These are in accordance with the reductive

change that occurred in bond strength. This previous increase in ARI may have some adverse effects, mainly in group 5 (15 minutes), like some difficulties in bracket debonding and enamel cleaning at the end of treatment steps.

Conclusions:

Under the conditions of this in vitro study, the results suggested a significant increase in shear bond strength of stainless steel brackets that bonded by self-etching primer adhesive. This change accompanied with the increase in the delay of application time from 3 seconds, 2 minutes, 10 minutes and 15 minutes until 20 minutes; here there was a reduction in the bonding strength. Moreover, a significant correlation was found between shear bond strength and the delay in application time. The ARI reported a decrease of bracket failure rate at the tooth / adhesive interface accompanied the increase of application time until 20 minutes as reverse results were recorded.

This new bonding agent is simple, universal, easy to use; also the high values of shear bond strength that recorded in this study still near the required normal orthodontic force.

More laboratory investigations are indicated about the point of delaying in application time to find the accurate time that should not overcome. This investigation must be followed by a clinical trial to explore it's benefits for the patients and clinicians.

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