

Comparison on Shear Bond Strength between Precoated and Non-Precoated Adhesive Technique (an in vitro Study)

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Abstract

The aim of this study was comparing shear bond strength between precoated adhesive and non-precoated adhesive on metal bracket. Thirty extracted human maxillary first premolar were randomly divided into three groups (10 per group). The group 1 was bonded with metal bracket with precoated adhesive technique. The group 2 was bonded with metal bracket with non-precoated adhesive technique, and group 3 was a control. Testing shear bond strength was done 30 minutes after bracket bonding with Autograph universal testing machine with cross-head speed of 0,5 mm/min. It took significantly ($p < 0.05$) shear bond strength between with precoated adhesive technique and non-precoated adhesive technique. The precoated adhesive technique had greater shear bond strength (11,575 MPa) than non-precoated adhesive technique (10,061 MPa). The control group had the greatest shear bond strength (12.158 MPa). There were difference in shear bond strength between precoated adhesive technique and non-precoated adhesive technique.

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Introduction

Bonding procedure is a standardized procedure in fixed orthodontic treatment. Bracket bonded on teeth is affected by several factors which are the bracket base size, design of the mesh bracket, concentration, etching, filler content level in adhesion, also adhesive material application technique.¹⁻³ During orthodontic treatment, the bracket might get shear stress, pull, torsion resulting in detachment of the bracket.⁴

Several studies concerning the bracket bond strength bracket reported, about 5.8-18.8%, there were bond failure on the posterior teeth, especially the maxillary premolar.^{2,5,6} Bond failure will be an unpleasant experience both for the operator and the patient, increase the chairside time, increase the control cost, and take longer treatment time.^{2,7}

Evolving over time, various technologies

on bracket, etching material and adhesive had emerged featuring more aesthetic bracket materials, bracket mesh design, flour-release adhesive, antibiofilm, more time-saving bonding technique which already has both etching and primer, adhesive that has previously adhered to bracket base, and adhesive that has adhered to the adhesive bracket base which its quantity fit the bracket base when being pressed, so the operator does not need to clean the adhesive materials residue before light curing.⁸⁻¹⁰

Pre-coated adhesive is well-known for its quality and quantity which are consistent on the bracket base, higher filler content level than the general ones, and minimizing the contaminant during the bonding procedure and shortening chairside time.⁹

Different from the shear bond strength between the material of the restoration with enamel, that is above 20 MPa, the bond strength suggested in orthodontics is optimum and temporary in which ranging from 2.8 to 16.6 MPa in order to prevent enamel damage.¹¹⁻¹³ Therefore, this study was concerning the best feature of pre-coated adhesive technique, so it's necessary to know this bond strength technique. The bond strength was tested immediately after the bonding step which called initial shear bond

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strength. This study also aims to know where bond failure may occur which was evaluated by observing residual adhesive on teeth after shear bond strength test, and to know the effects of the bond strength to enamel since the end of shear bond test until the adhesive cleaning.

Materials and Methods

Thirty of recently extracted upper first premolar human teeth to the necessity of orthodontic treatment from patients aged 20-30 were collected for this study which were having visually smooth looking buccal surface and without any color changes, decalcification, cracked enamel caused by extraction process, fracture or caries. This study used metal bracket with precoated adhesive and Victory metal bracket from 3M Unitek with single mesh. The bracket base area was 11.84 mm².

Teeth sample preparation

The teeth were cleaned under running water with fine brush, soaked in timol 0.1% for 24 hours. The teeth' roots were cut and its enamel were preserved in aquades which was replaced daily. The teeth were planted in acrylic tube with 15x8 mm size and divided into three groups. The bonding procedure is different for each group.

Bonding procedure

All teeth were polished with pumice and water. Bracket placement was guided following the marks on acrylic tube based on the bracket application position for premolar teeth. This study used the same weight which was 300 gr weight placed on glass plate until the excess adhesive came out from the base of bracket. Afterward, the residual adhesive got cleaned (Figure 1). The light curing was done in 10 seconds from mesial and 10 seconds to distal.

- Group I: Self-etching primer was applied on the buccal surface of the teeth for 5 seconds. Metal bracket with precoated adhesive was directly positioned on the buccal side of teeth according to the marks on acrylic.
- Group II: Self-etching primer was applied on buccal surface of the teeth for 5 seconds, Transbond XT adhesive paste was applied using plastic instrument which had been marked with 2 mm width to the base of bracket.
- Control group: Phosphoric acid 37% was

applied on buccal surface of the teeth for 30 seconds, then rinsed for 20 seconds and got dried, continued with primary coating for 2 seconds. Transbond XT adhesive paste was applied using plastic instrument which had been marked with 2 mm width from the base of the bracket.

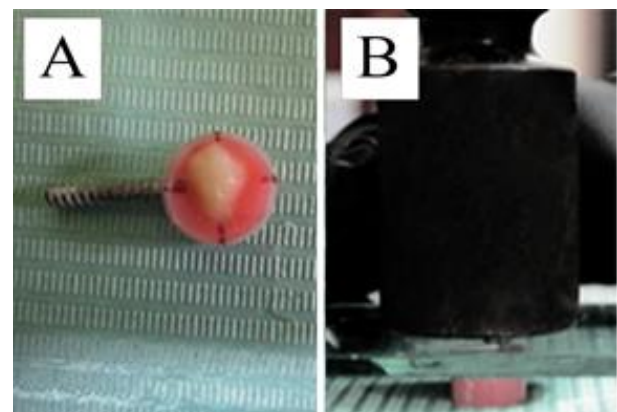


Figure 1. A. Tooth that had been planted in plastic tube which had been marked for bracket application procedure. B. A 300 grams weight placed on top of glass plate as bracket stressor, before the light cure usage.

Shear bond strength test

Teeth with bracket was given stainless steel wire with 0.016-inch of diameter, then tied with ligature wire. The sample was tested with Autograph with cross-head rate at 0.5 mm/minute in which its force was in parallel direction towards mesiodistal of teeth until the bracket detached (Figure 2). The shear bond strength value was converted into MPa (Megapascal) obtained by multiplying the result of the test on Autograph by 9.807 then divided by the area of base of bracket which was 11.84 mm².

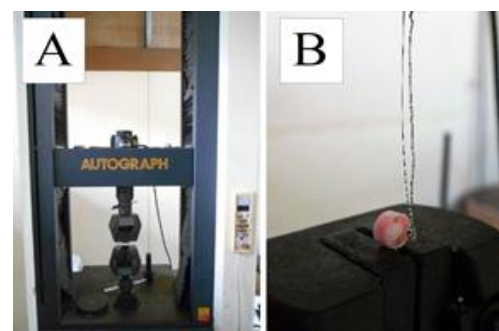


Figure 2. A. The Autograph. B. Shear bond strength test.

Calculation of residual adhesive on teeth

SEM Test was done on 3 samples from

each group (total sample were 9). The results were images with 50x magnification in jpeg format. Residual adhesive was calculated using Autocad 2016. The output from Autocad was in the form of the adhesive area in mm². The percentage of adhesive obtained by dividing the adhesive area by the bracket area which was 11.84 mm² then multiplied it by 100% (Figure 3).

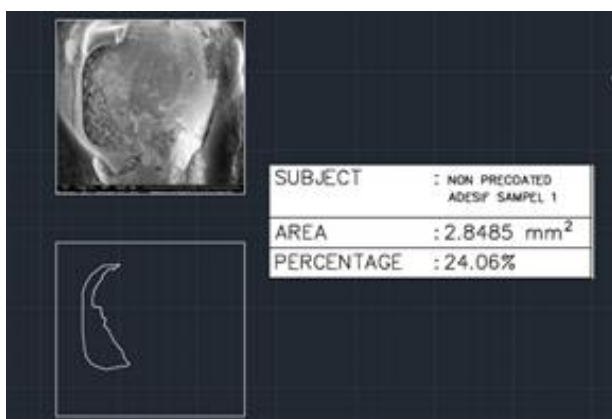


Figure 3. Calculation of the area of adhesive which remains on teeth using Autocad 2016.

Statistically analysis

The result data of shear bond strength was tested with Kolgomorov-smirnov and levene test, showing homogenic data in normal distribution. Then, the data was tested using one-way ANOVA and post hoc test.

Results

The shear bond strength of precoated adhesive was higher than non-precoated group in which both using self-etching primer technique. There was no difference between shear bond strength of precoated group and control group. In control group, more residual adhesive found on buccal surface of the teeth.

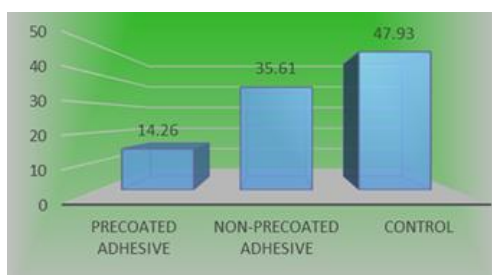


Figure 4. Percentage chart of residual adhesive on teeth in every group.

Discussion

The bond resistance of bracket for not to be detached by the shear force was called shear bond strength. Unlike the previous studies, the shear bond strength in this study were tested in 30 minutes following the direct bonding or initial shear bond strength, which described the bracket bond strength right after bonding step until the initial wire placement.

The purpose of using upper first premolar teeth in this study was to reduce the influence of teeth anatomy variations, and to ease obtaining the sample because those teeth commonly get extracted during orthodontic treatment. Most studies also reported that bond failure mostly happened on premolar teeth.³ Therefore, upper first premolar which representing the posterior teeth was used. If the shear bond strength test result turns out good, then its shear bond strength will be considered good for all types of teeth.

In this study, every recently extracted premolar teeth was cleaned under the running water and stored in timol 0.1%, which acts as antimicrobial and antifungal, for single day. The aquades was also replaced daily to prevent bacteria growth.^{1,14}

Before the etching process, enamel had two scrape directions which were vertical and diagonal. The enamels with self-etching primer applied were dominated by vertical and deeper scrapes. On enamel with phosphoric acid 37% applied on, there were scrapes in vertical, diagonal and horizontal directions with various depth (Figure 5). The main cause of greater number and deeper scrapes on enamel on teeth group applied with phosphoric acid 37% is the chemical reaction which was more aggressive than the one using self-etching primer.¹⁵

Etching step also determines the shear bond strength value. The principle of the etching process is that the etching will dissolve hydroxyapatite from enamel so that it forms porosity. The porosity will be filled with adhesive material.¹⁶ The greatest shear bond strength in this study was in control group using total etching technique with phosphoric acid 37%. The microporosity formed on the etching process with self-etching primer and total etching were having different patterns (Figure 6).

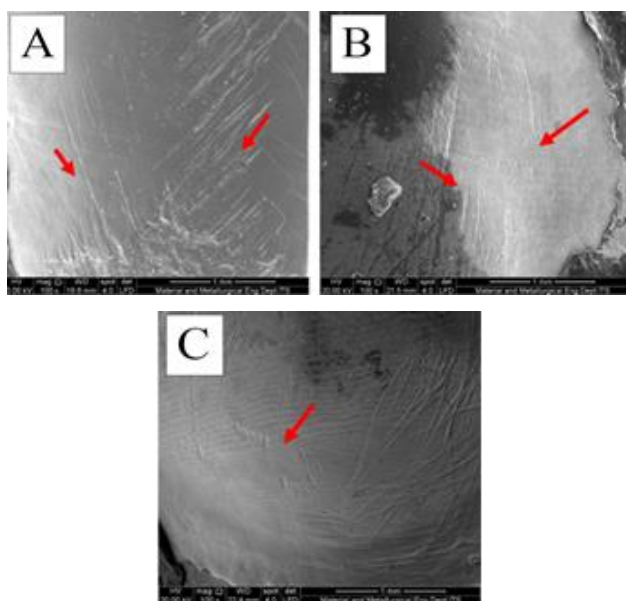


Figure 5. The enamel condition from SEM result with 100x magnification, the arrows indicate the scrape's directions. A. Enamel before etching process. B. Enamel after self-etching primer application, C. Enamel after phosphoric acid 37% application.

In pre-coated and non-pre-coated adhesive groups which used self-etching primer, the patterns were only microporosity. Microporosity on control group using total etching with phosphoric acid 37% were connected to each other resulted in greater microporosity than pre-coated and non-pre-coated group which used self-etching primer technique. Similar to what Zope et al.¹⁷ stated, total etching technique using phosphoric acid 37% caused more enamel ripped off leading to bigger and deeper microporosity.

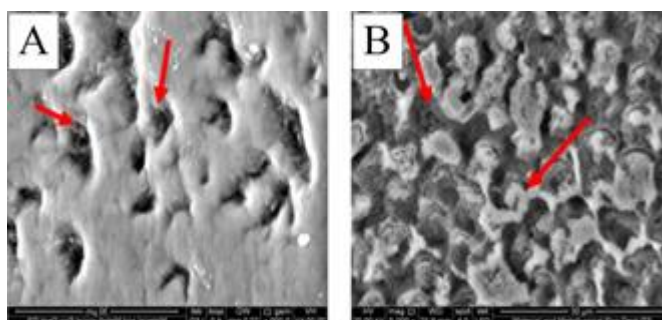


Figure 6. Microporosity of enamel from SEM result with 5000x magnification, the arrows indicate microporosity: A. After self-etching primer application. B. after phosphoric acid 37% application.

The shear bond strength test was done in 30 minutes after direct bonding without being soaked in saliva and incubation for 24 hours or more. It was done like orthodontic practice simulation in which braces placement and its ligation usually done in few minutes after direct bonding. The procedure of in vitro study which tests the shear bond strength in 24 hours after direct bonding does not reflect the clinical orthodontic practice where initial wire is applied in 10 to 30 minutes after the direct bonding phase done. The teeth sample stored in artificial saliva after direct bonding or on bracket with teeth applied on it are also not affecting the amount of shear bond strength value during the direct bonding process.¹⁸

After the test, the obtained shear bond strength values were different (Table 1). The highest shear bond strength value was in control group, followed by the group using pre-coated adhesive and self-etching primer, and the last was the non-pre-coated adhesive group which also using self-etching primer but its adhesive material were applied manually.

| Groups | Means (MPa) | SD | P |
|---------|-------------|------|------|
| I | 11.5750 | 1.08 | 0.01 |
| II | 10.0610 | 0.75 | |
| Control | 12.1580 | 1.44 | |

Table 1. The result of one-way ANOVA showing the shear bond strength difference between three groups.

Ogaard and Fjield¹⁹ stated that the recommended optimum shear bond strength value range was between 5.9 MPa to 13.3 MPa. Other studies reported the range was between 2.8 to 16.6 MPa.^{4,11} According to Vinagre et al.²⁰, the maximum values of the shear bond strength can not be over 11-25 MPa. The optimum values of shear bond strength are different because the previous researches also used different techniques and methods. In this study, the shear bond strength value on three groups were still within the recommended range.

In pre-coated adhesive group, the shear bond strength value was higher than the non-pre-coated group which both using self-etching primer. Pre-coated adhesive which was used had greater filler content than adhesive paste which was applied manually.

According to Scoulgall-Vilchis et al.²¹, the presence of filler particles made the adhesive materials had better mechanical properties, which also improving the resin resistance, improving its strength, reducing dimension changes, and increasing the viscosity. The increased viscosity can improve the bond during the bracket placement and also not easily displaced before getting pressed and during light curing.

Based on SEM result, after the shear bond strength test, the cracks on enamel started to form (Figure 7). Enamel on precoated adhesive group developed cracks even though they were few in number and not deep. Enamel on non-precoated adhesive group were seen becoming deformed as a result to the shear bond strength. Enamel on control group developed deeper cracks, even some of it were ripped off. Hashimoto et al.¹² stated that the greater the shear bond strength is, the greater the risk of damage of the enamel during the bracket removal, which later reduce the enamel resistance and increase the risk of decalcification.

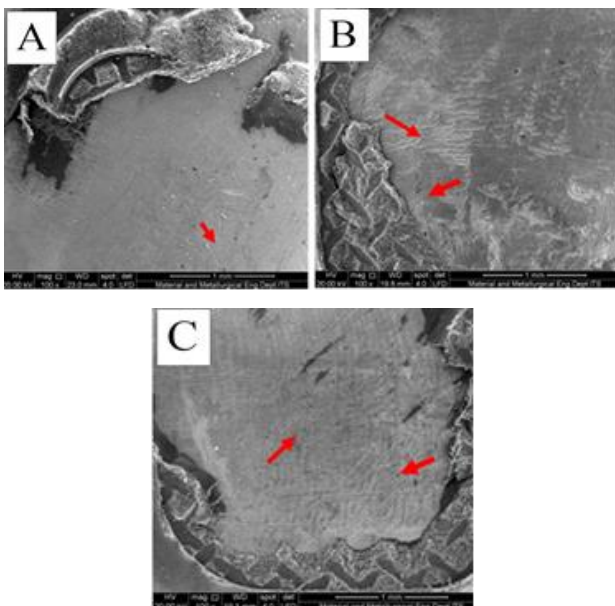


Figure 7. Enamel condition after the shear bond strength test from SEM result with 100x magnification, the arrows indicate cracks on enamel. A. Group I, B. Group II, C. Control Group.

In precoated and non-precoated adhesive groups which both using self-etching primer technique resulted more minimal crack than the groups using non-precoated with total etching technique. In accordance with the statements

from Hashimoto et al.¹² and Protasio et al.²², the total etching technique, phosphoric acid 37% could result in enamel demineralization for 5-60 μm depends on its etching time.

The detachment of bracket during orthodontic treatment will leave the adhesive either on enamel or the bracket. The amount of its residue is evaluated in order to know where the fracture point or site of bond failure, whether it is between the bracket and the adhesive material or between adhesive material and the enamel. The bond failure between adhesive materials and bracket is marked with more residual adhesive left on enamel. Meanwhile, the bond failure between adhesive material and enamel is marked by more residual adhesive left on the bracket base.^{23,24}

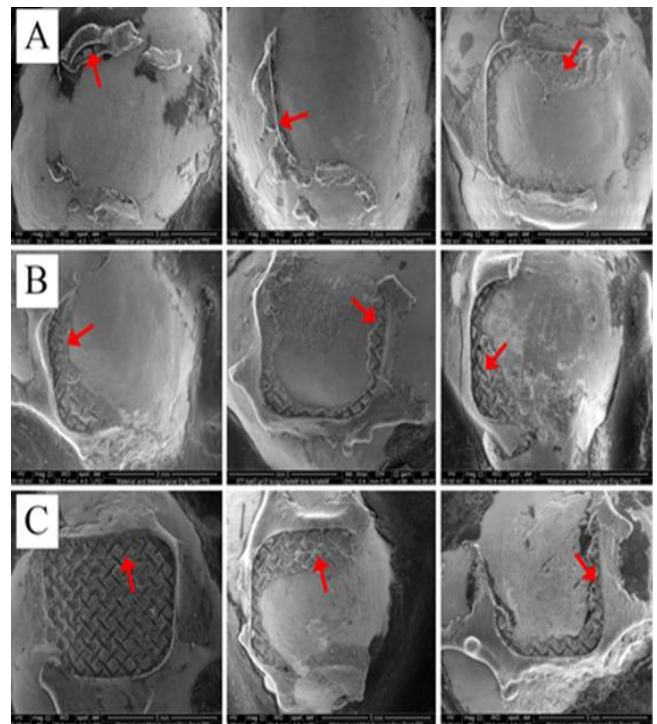


Figure 8. Adhesive remnant on buccal surface of the teeth. A. Group I, B. Group II, C. Control Group.

The amount of residual adhesive on teeth was calculated using AutoCAD 2016 in purpose to have objective measurements. The image of SEM showed that control group had the most adhesive remains on teeth (Figure 8). The least adhesive was in precoated adhesive. It is indicated that the bond strength between adhesive and bracket base was better than the

bond strength between adhesive material and enamel of precoated adhesive group, whereas in control group, the bond strength between adhesive material with enamel was better than the bond strength of adhesive material and the bracket base. Precoated adhesive, though having higher shear bond strength value, it remains minimal adhesive.

In this study, SEM test was done after the adhesive got cleaned with the same adhesive cleaning procedure which used tungsten carbide burs. The result of SEM with 1000x magnification showed enamel of precoated adhesive group with less damage than enamel of non-precoated adhesive and control group (Figure 9). It means, if the fracture point is less likely to formed between adhesive and enamel, then it will reduce the risk of enamel damage during adhesive cleaning. Lobato et al.⁷ stated that the more adhesive remains on enamel after debonding, the greater the risk of iatrogenic trauma likely to occur because of the adhesive removal procedure.

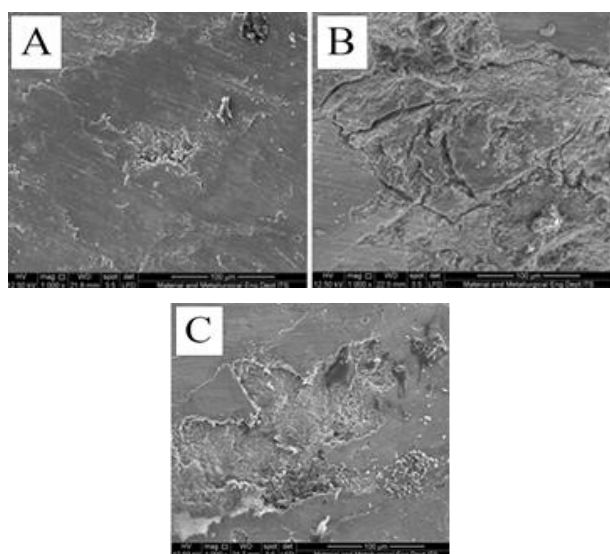


Figure 9. The enamel condition after the adhesive cleaned on SEM result with 1000x magnification. A. Group I, B. Group II, C. Control Group.

| Groups | I | II | Control |
|---------|-------|-------|---------|
| I | - | 0.006 | 0.259 |
| II | 0.006 | - | 0.000 |
| Control | 0.259 | 0.000 | - |

Table 2. The result of post hoc test showing the shear bond strength difference between three groups.

The results of this study showed that, after direct bonding phase, the bond strength of precoated adhesive with self-etching primer technique was better than non-precoated adhesive because the value of its shear bond strength was equal to the shear bond strength of control group which used total etching technique with etching material phosphoric acid 37% (Table 2). However, the three groups were equally having the shear bond strength which could be used in clinical practice in orthodontics because the value of its shear bond strength on both two groups was still within shear bond strength range that was recommended.

Precoated adhesive with self-etching primer technique can be an alternative choice because it offers more shortened chairside time, consistent adhesive quantity on the bracket base, less contamination during the direct bonding step, also minimal residual adhesive after debonding yet still having the same adhesion with usual procedure. The other advantage of precoated adhesive on metal bracket is its easiness to clean the adhesive before the light curing because of the adhesive residue which came out from the bracket base after being pressed was very minimal even nearly nothing which made the possibility of the formation of white spot became lessen.

However, it is necessary to consider from the economy aspect, because the price of bracket with precoated adhesive is more expensive and its way to store that requiring a dark place. The non-precoated adhesive with self-etching primer could be an ultimate choice in this thing because besides it is not that expensive, the non-precoated adhesive usage with self etching primer also shortened the chairside time with its shear bond strength which is in between precoated adhesive group and control group.

This study also suggests that self-etching primer usage during direct bonding process is more recommended than etching with phosphoric acid 37% in total etching technique because self-etching primer does not dissolve the enamel that much, and also the microporosity that was formed are smaller.

It can be concluded that the initial shear bond strength test, the precoated adhesive group with self-etching primer technique had greater shear bond strength than the non-precoated adhesive group with self-etching primer

technique. The control group which was non-precoated adhesive with total etching technique had greatest shear bond strength. The microporosity that occurred in control group which used total etching were greater both in its size and number resulting the greatest shear bond strength. Precoated and non-precoated adhesive group with self-etching primer technique had less microporosity resulting the shear bond strength of those two groups were less than the control group's. Residual adhesive after the shear bond strength test on precoated adhesive was less than non-precoated group's.

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