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Bonding and Re-Bonding Strength among three Orthodontic Adhesive Systems with Recycled Brackets

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ABSTRACT:

Study background: In order to avoid bracket failure, good and high bond strengths are required during treatment while brackets in function. Surface treatment of rebonded enamel, as well as recycled bracket base will improve contact area of the bracket to the tooth.

Objectives: to compare SBS of different composite brand with famous one and examine the effect of enamel condition with different etching time in combination with in-office bracket base condition with green stone and sandblasting, however, is yet not well described.

Methods: In this study we examine clinical SBS range and adhesive remnant index(ARI) of two different adhesive resin brands Xihubiom light cured (Westlake Biomaterial CO.LTD, China), and Tianjin chemical-cured (Tianjin Synthetic Material, tianjin city, Road 29,China) compared with famous and widely used Transbond XT light cured (3M Unitek, Monrovia, Calif). After that, debonded brackets were recycled with two methods; sandblasting treatment using 50 µm aluminum oxide particles under a pressure of 0.45 MPa, and green stone drilling. In all enamel samples, residual resin were removed by tungsten carbide bur and etching rebonded enamel surface carried under various etching time; 30s, 60s, and 0s etching was done. Samples were rebonded to enamel surface by Xihubiom light cured composite. All specimens were debonded using Eplexor 500N (Gabo, Germany) testing machine with crosshead speed of 1 mm/min, then shear bond strength and rebonded strength were measured, respectively. The ARI was re-scored .Scanning electron microscope (SEM) ([Jeol/JLM-5200, Tokyo, Japan) for enamel surface after debonding.

Results: Transbond XT resin (18.23MPa) had higher shear bond strength than any of the other bonding material but there were no statistically significant at P>0.05, among Transbond XT, Xihubiom resin(16.99MPa)and Tianjin resin (16.85MPa). Samples re-cemented with Xihubiom resin hadrebonded strength values as follow; sandblasted brackets with enamel etching for 30 seconds SD3 (13.49MPa) had the highest rebonded strength values than the others. There were no statistically significant at P>0.05 among SD3, sandblasted brackets with enamel etching for 60 seconds SD6 (12.39MPa), drilled brackets base with enamel etching for 30 seconds DD3 (7MPa), and drilled brackets base with enamel etching for 60 seconds DD6 (6.18MPA). However, SD3, and SD6 had RBS valuesstatistically significant P<0.05 thandrilled brackets base with no enamel etching DD (4.58MPa) and the value for SD3 were statistically significant P<0.05than sandblasted brackets with no enamel etching SD (5.85MPa). Significant differences were found in the ARI scores.

Conclusion

1) The shear bond values of 3 adhesives are clinically acceptable.
2) For economic saving we recommend the use of Xihubiom resin for bonding and rebonding brackets.
3) Recycling brackets base with 50 µm aluminum oxide sandblasting and enamel etching for 30 seconds had the best rebonding strength when compared to green stone treated brackets base.
4) In the second debonding one hour After cementation, enamel re-condition with tungsten Carbide bur only is insufficient as a conditioning procedure but, if combination with acid etching, reasonable rebonding strength can be achieved.

KEY WORDS:- Etching, Shear bond strength, Rebonding, Recycled brackets.

I. INTRODUCTION

During orthodontic treatment an important aim is to increase patient comfort, simplify and decrease chairtime. Orthodontic bonding material was introduced in 1965 and is considered a significant discover in orthodontic field [1]. Adhesion process occurs through microscopic interlocking between the adherent and the brackets with the adhesive. Technical Advances in adhesive material and the introduction of new materials and bonding techniques have greatly influenced and revolutionized orthodontic practice [2].

With all of the currently available adhesive systems, many factors increase acid etching quality in which concentration of the etching [3], depth of penetration of the etching, consistency of the etching material. However, etching material type as well as the duration of etching [4], and decalcification of the enamel surface[5], can reduce or enhance the effect of the etching procedure. Enamel surface bonded with orthodontic brackets should be cleaned and etched with phosphoric acid for 30 to 60 seconds, rinsed thoroughly with water, dried, and coated with resin adhesive before bracket bonding with resin cement. Traditionally the enamel surface has been prepared by etching with phosphoric acid at concentrations ranging from 35% to 40% for 15 to 60 seconds[6,7], followed by rinsing and drying of the surface. Phosphoric acid shows noticeable effects in which dissolution of hydroxyl apatite of enamel causing demineralization of the most superficial layer of enamel[8]. Phosphoric acid can make a selective dissolution of enamel prism cores and form microporosity of the enamel surface creating about 25-μm[9,10]. Although this is a simple and effective technique, the needs to etch, rinse, and dry the enamel while the environment isolation can be satisfying.

In some clinical situations, especially when patient compliance is an issue, etched enamel contamination before bracket bonding will dramatically affect bond strength, and this might compromise brackets and appliance stability [11,12]. Application of adhesive resin systems to acid-etched enamel allow an optimal bonding of orthodontic brackets to tooth surface, which will improve and simplify placement of fixed orthodontic appliances by widen the scopes in Orthodontics. The objectives of brackets debonding are to remove the attachment and all the adhesive resin from the tooth and to restore the enamel surface as possible to it is original form. To achieve these objectives, correct bonding and debonding are of fundamental importance. In orthodontic treatment, many factors affecting brackets debonding procedures. The most important of which are types of brackets material, bracket base shape, adhesive used, instruments used for bracket removal, and the armamentarium for resin removal[13,14,15,16]. The ideal orthodontic bracket bonding method should provide adequate bond strengths to satisfactorily retain orthodontic brackets, withstand the forces of mastication, the stress exerted by the arch wires and patient abuse, and, if possible, help prevent or reduce the amount of demineralization during treatment. At the same time the bond strength should be at a level to allow for bracket debonding without causing damage to the enamel surface. Various studies have suggested bond strengths ranging from 6 to 8 MPa as being adequate for clinical situations [17]. No reliable protocol for Ideal estimating strength properties has been described. However, the use of shear testing machine which contains a rigid and stable part that record and produce pure shear forces; Therefore, constant loading rate produced by universal testing machine whereas the rate of loading for in vivo debonding is not standardized or constant. In vitro study, researchers use extracted teeth which kept in distilled water which in fact are much drier than vital teeth and, therefore, more enamel damage is susceptible. Therefore, values obtained in vitro bond strength might be higher than those obtained in vivo. However, it is obvious that the in vitro studies provide a guide for the clinician in selecting the bracket/adhesive of his choice to be used in vivo.

In chairside treatment, rebondedrecycled brackets had been considered during treatment duration because of their repeated falling and re-correction of their positions [18]. Economic saving considered a major advantage for recycling brackets, which could be as high as 90 per cent, due to the fact that patient receive orthodontic treatment duration range up to 2 years, therefore, a single bracket can be reused up to five times[19]. The effectiveness of these methods has been evaluated in several investigations. However, using a high-speed stream of aluminum oxide by compressed air, removes unfavorable oxides, resin and increases surface energy and bonding surface area by increasing the surface roughness [20,21]. Recently, it was reported that, shear bond strength (SBS) values are compared before and after sandblasting are equivocal. Some investigators have reported that rebond SBS values were higher after sandblasting, but others reported no significant differences [22,23,24]. Roughening a debonded attachment with a greenstone has been reported to lead to a smoother surface devoid of undercuts [25,26]. The effectiveness of chairside methods has been evaluated in several studies. Commercial recycling, whether thermal means (e.g. direct flaming), mechanical means (sandblasting or rotary burs and stones), and chemical means, leads to a degree of metal loss in certain areas of the bracket and a reduction in the diameter of the mesh strands. Therefore, some authors reported that bond strength of rebonded brackets decrease significantly [27,28], will others reported that there is an increase in bonding strength of rebounded brackets [27].

The purposes of the present study were (1) to identify wither the shear bond strength values of 3 different types of composite resin are clinically acceptable, (2) to find cheap and economically new resin material (3) to examine the rebonded strength of new resin material brand, and (4) to compare the effect of sandblasting, and drilling brackets received different tooth surface etching time on the RBS cemented with the same orthodontic composite resin.

II. MATERIALS AND METHODS

2.1 Sample preparation

Fifty-four freshly extracted human premolars extracted with orthodontic indications were used in this study. The teeth were stored in 0.1% thymol solutions at room temperature immediately after extraction and were used within 5 weeks. Teeth that had hypoplastic enamel, fractures, or caries were excluded. The root of each tooth bonded to the bracket was cut off with a separating disk. The teeth were embedded in acrylic resin with the buccal surfaces available for bonding (the buccal surface of each tooth was monitored for alignment with the force vector of the testing machine). After the acrylic resin had been cured, the tooth surfaces to be bonded were cleansed with pumice and a rubber prophylactic brush for 10 seconds.

2.2 Brackets bonding

(Table 3.1) Three different adhesives were tested for SBS testing (n=18),Transbond XT light cured (3M Unitek, Monrovia, Calif), Xihubiom light cured (Westlake Biomaterial CO.LTD, China), and Tianjin chemical-cured (Tianjin Synthetic Material, tianjin city, road 29, China).

Transbond XT light cured (3M Unitek, Monrovia, Calif), and Xihubiom light cured (Westlake Biomaterial CO. LTD, China) samples were etched with 37% phosphoric acid for 30 seconds, thoroughly rinsed for 20 seconds with water, and dried with a moisture-free and oil-free stream of air. The enamel surface was inspected for the frosted appearance that indicated adequate etching. A thin coat of primer was painted on the enamel surface and further thinned with a stream of moisture-free and oil-free air. Metal standard edgewise brackets (3M Unitek, Gemini brackets). Then the brackets were bonded perpendicular to the long axis of the teeth in the middle of the buccal side with the distance of 4 mm from the buccal cusp. Brackets with its uncured composite pad were pressed firmly against the enamel surface, and excess adhesive was removed before curing. Each sample was light-cured for 40 seconds with a quartz-tungsten-halogen dental curing light with a radiance of 500 mW/cm2. The curing light was held against the bracket and tooth on the mesial aspect for 20 seconds followed by 20 seconds against the distal aspect.

Tianjin chemical-cured (Tianjin Synthetic Material, tianjin city, Road 29, China) were etched with 37% phosphoric acid for 30 seconds. Mixing was done according to the manufacture, new mixing Pad and clean spatulas was used for bonding brackets. Brackets were placed in and left 30 sec as recommended by the adhesive manufacturer to achieve maximum retention. All the samples were handled according to the previously described methods.

2.3 Debonding, testing shear bond strength and evaluation of residual adhesives index:

A chisel-shaped steel rod with (figure 1), a flat end was attached to Eplexor 500N testing machine (Gabo, Germany). An occlusogingival vertical shear force was applied 24 hours after bonding to the occlusal sides of bracket wings at a crosshead speed of 1 mm/ min (figure 2). The maximum necessary load to debond or initiate the bond fracture was recorded in Newton units and was used to calculate the SBS in Megapascal units (MPa) by dividing the magnitude of force by the size of bracket base's area.

Afterward, the experimental specimens were examined with a stereomicroscope Luckbird (Jiangsu, China) at 10_ magnification (Table 3.2). The amount of remaining adhesives after bracket removal was assessed and scored with ARI scores ranged from 0 to 3, with 0 indicating that no adhesive remained on the tooth surface, 1 showing that less than half the adhesive remained on the tooth surface, 2 indicating that more than half of the adhesive remained on the tooth surface, and 3 meaning that all adhesive remnants on the tooth surface had a distinct impression of the bracket base.

2.4 Resin removal and enamel surface etching

Prior to acid etching, all samples were gently air dried to remove the excess water and then 37% phosphoric acid was applied(Table3.3). Teeth were randomly divided into 6 equal groups (n=9) according to etching time with 37% phosphoric acid. Etching time was done as DD6 group, and SD6 group for 60s, DD3 group, and SD3 for 30s. No etching was done to DD and SD groups.

All of the resin remained on enamel surface was removed by tungsten carbide bur. The appearance of a smooth enamel surface with no trace of composite was regarded as a sign that removal of all residual adhesive had been completed.

Fig 1: A chisel-shaped steel rod witha flat end.

2.5 Re-bonding using recycled brackets and resin adhesive:

Brackets base recycling were carried outrandomly by sandblasting and green stone drilling (n=27). Table 3.3, sandblasting was carried out Rondoflex sandblaster (kavoElektrotechnisches, West Germany) using 50 µm aluminum oxide particles under a pressure of 0.45 MPa for 20 seconds. The distance between the surface of the bracket base and the tip of the sandblasting hand piece was 10 mm. Green stone grinding on straight slow speed handpiece (NSK, Ti-205LM4, Japan) at a speed of 25,000 revolution per minute for approximately 15 seconds (n=27).

Xihubiom light cured (Westlake Biomaterial CO.LTD, China) was used to cement all recycled brackets. All 54 specimens were bonded according to the previously described methods.

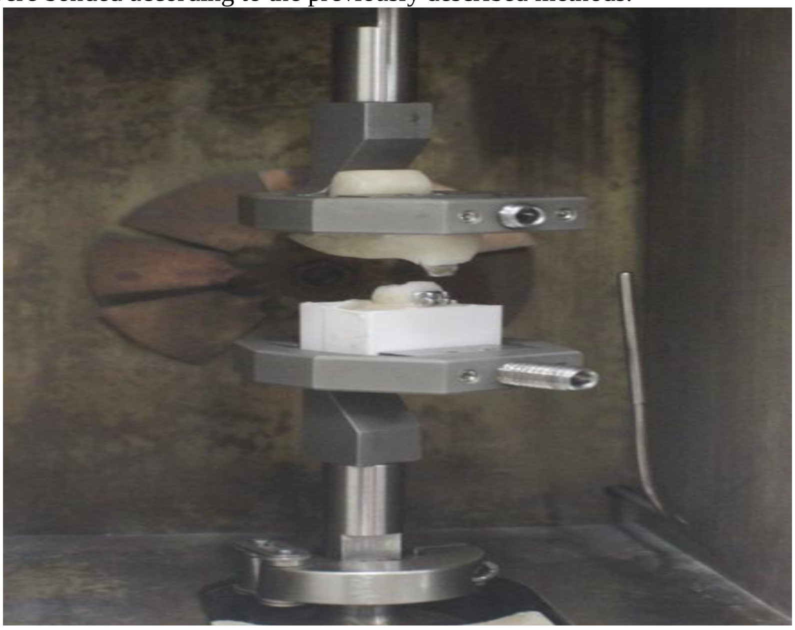


Fig 2: occlusogingival vertical shear force at Crosshead speed of 1 mm/ min

2.6 Testing the rebond strength (RBS), evaluation of residual adhesives index and SEM

Rebonded shear bond strength (Table 3.3) and adhesive remnant index evaluation (table 3.4) were done according to the previously described methods. Selected specimens were examined under a scanning electron microscope (Jeol/JLM-5200, Tokyo, Japan) at between X10 and X1000 magnification to show the characteristics of the debonded surfaces (Figure 3). All 6 groups were subjected to rebonding shear force one hour after bonding. Shear bond strength and rebonded strength were measured, respectively.

2.7 Statistical analysis

Statistical analyses were performed using the SPSS for Windows 7 version 16.0 (SPSS Japan Inc, Tokyo, Japan). Descriptive statistics including means, standard deviations, ranges, Scheffe´ post-hoc multiple comparisons(1-way ANOVA) with significance predetermined at P<0.05 were calculated for the SBS analysis.

The chi-square test was used to evaluate the ARI scores.

III. RESULTS

Table 3.1: SBS comparison of three resin materials

Adhesive Resin	Mean	SD	Minimum	Maximum	n
Transbond XT resin	18.23	4.19	10.76	25.87	*18*
Xihubiom resin	16.99	3.98	8.67	24.87	*18*
Tianjin resin	16.85	3.43	9.47	23.7	*18*

n; Number of samples
SD; Standard deviation
P >0.05

Table 3.1 shows the average SBS required to debond the brackets cemented with three resin materials. In Table 3:1, the mean SBS values of all three resin material were not significant difference (P >0.05). Therefore, mean SBS were higher than the 6.0MPa which considered adequate for bonding orthodontic brackets to teeth and the minimum requirement for clinical use [17]. Transbond XT resin (18.23MPa) had highest SBS when compared with the other bonding materials. Therefore, there were no significant differences among Transbond XT, Xihubiom resin(16.99MPa)and Tianjin resin (16.85MPa)

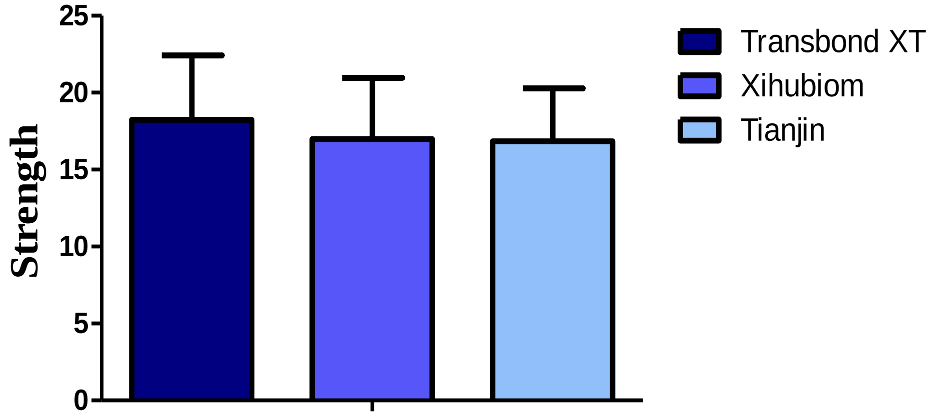


Fig 3: Relationship of mean shear bond strength for different resin materials. No significant Differences were noted between resin materials.

Table 3.2: Distribution of ARI of three resin materials

			ARI score (%)		
Adhesive Resin	n	0	1	2	3
Transbod XT resin	18	-	12(66.6)	4(22.2)	2(11.1)
Xihubiom resin	18	5(27.8)	13(72.2)	-	-
Tianjin resin	18	-	18(100)	-	-

ARI scores: 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; 3, all adhesive left on the tooth.
Chi-square 23.442
df= 6
P =0.001

Table 3.2 which describe The ARI scores for adhesive remaining after debonding. The chi-square comparisons (23.442) of the ARI scores among 3 materials indicated there were significantly different(P =.0001) among three materials. The least ARI scores was in Xihubiom group, in which there were 5 scores of 0; in other words, 27.8% of the samples had no residual adhesive after debonding, and 72.2% had less than half of the adhesive left on the tooth. In contrast, Transond XT, there were 2 scores of 3; in other words, 11.1% of the samples had all residual adhesive left on the tooth after debonding, 22.2% had more than half of the adhesive left on the tooth, and 66.6% had less than half of the adhesive left on the tooth. However, Tianjin had 18 scores of 1; in other words, 100% of the samples had less than half of the adhesive left on the tooth. No enamel fracture was noted among any samples tested on the Eplexor N500 testing machine.

Table 3.3: MPa comparison between 6 groups; groups SD, SD3, and SD6 referred to S which means brackets base sandblasting, D which means enamel drilling with tungsten bur, while 3 and 6 means etching time in seconds; groups DD, DD3, and DD6 referred to D which means brackets base drilling with green stone, D which means enamel drilling with tungsten bur, while 3 and 6 means etching time in seconds.

Group	Resin material	Bracket base condition	Enamel surface condition	n	MPa+SD
Group SD*	Xihubiom	Sandblasting	tungsten carbide bur only	9	5.85±4
Group SD3	Xihubiom	Sandblasting	tungsten carbide bur +Etching 30”	9	13.49±6.07
Group SD6**	Xihubiom	Sandblasting	tungsten carbide bur+ Etching 60”	9	12.39±5.38
Group DD *	Xihubiom	Drilling	tungsten carbide bur only	9	4.58±2.26
Group DD3	Xihubiom	Drilling	tungsten carbide bur +Etching 30”	9	7±4.65
Group DD6	Xihubiom	Drilling	tungsten carbide bur+ Etching 60”	9	6.18±4.7

n; Number of samples
SD; Standard deviation
MPa: Megapascal units
*Significant difference between groups. Two groups with the same star position and number are significantly difference; P <0.05

Table 3.3 shows shear bond strength of Scheffe´ posthoc multiple comparisons for different enamel and brackets surface treatment cemented with Xihubiom cement. Group SD3 (13.49MPa) had higher MPA values than the other groups. Therefore, there were no significant differences (P >0.05) among groups SD3, SD6 (12.39MPa), DD3 (7MPa), and DD6 (6.18MPA).
Groups SD3 and SD6 had values were significant differences (P <0.05) when compared with group DD (4.58).
Group SD3 had values were significant differences (P <0.05) compared with group SD (5.85).

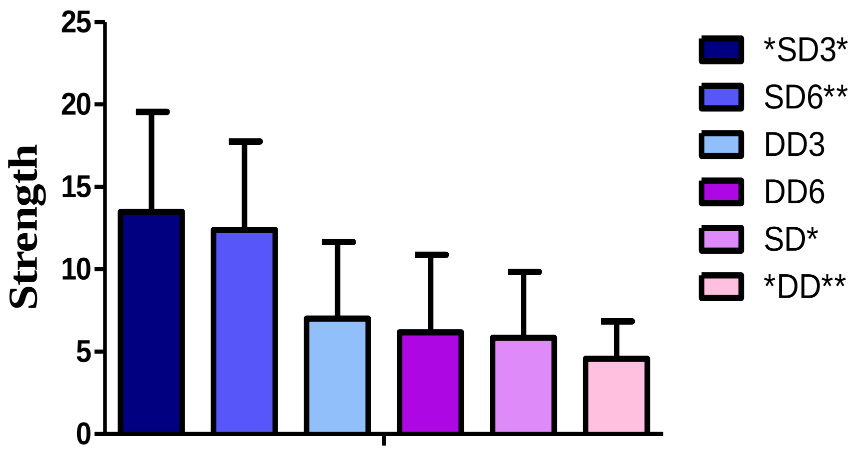


Fig 4: Relationship of Xihubiom resin shear bond strength under different enamel and brackets surface condition; there were no significant differences (P >0.05) among groups SD3, SD6, DD3, and DD6.Groups SD3 and SD6 had values were significant differences (P <0.05) when compared with group DD. Group SD3 had values were significant differences (P <0.05) compared with group SD.

Table 3.4: Distribution of ARI through 6 groups

			ARI score		
Group	n	0	1	2	3
Group SD	9	3(33.3)	6(66.7)	-	-
Group SD3	9	-	2(22.2)	5(55.6)	2(22.2)
Group SD6	9	1(11.1)	5(55.6)	2(22.2)	1(11.1)
Group DD	9	8(88.9)	1(11.1)	-	-
Group DD3	9	1(11.1)	5(55.6)	3(33.3)	-
Group DD6	9	1(11.1)	5(55.6)	3(33.3)	-

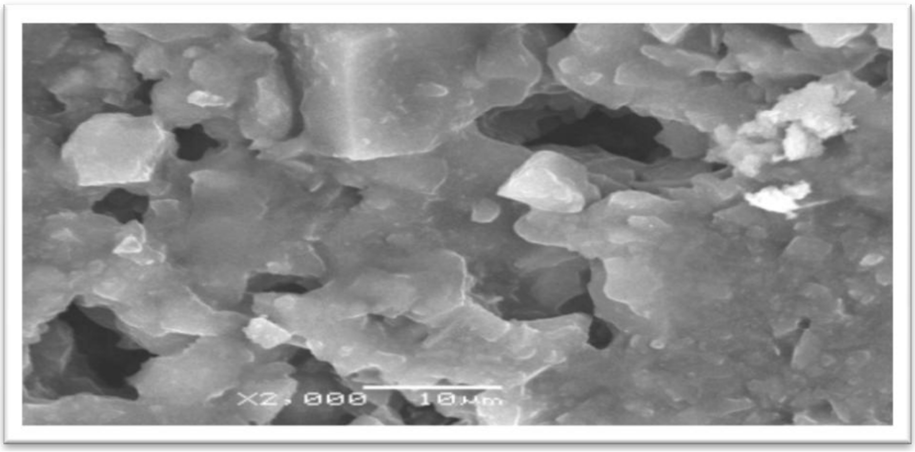
ARI scores: 0, no adhesive left on the tooth; 1, less than half of the adhesive left on the tooth; 2, more than half of the adhesive left on the tooth; 3, all adhesive left on the tooth.
Chi-square 39.264
df= 15
P =0.001

In SD group, 66.6% of the samples had ARI scores of 1, and 33.3% had ARI scores of 33.3%, indicated that less than half of the residual adhesive left on the tooth.
In DD group, 88.8% of the samples had ARI scores of 0, and 11.1% had ARI scores of 1, indicating that no adhesive left on the tooth.

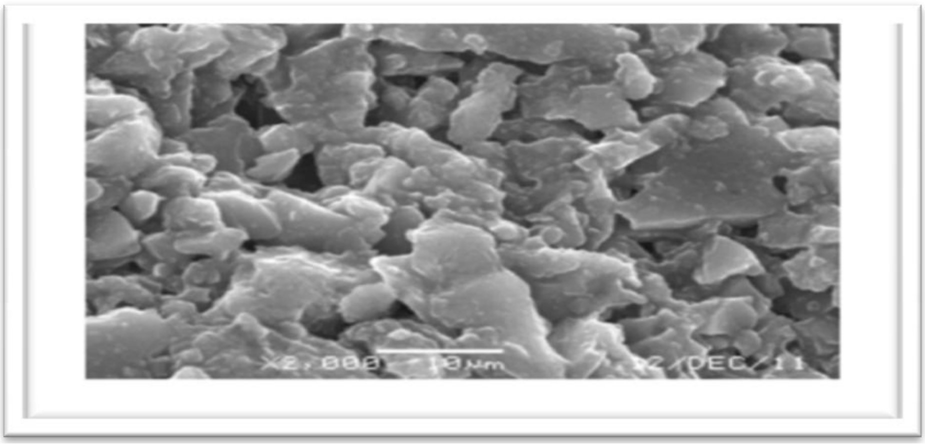
DD3 group and DD6 group showed similar bond failure. In both groups, 11.1% of the samples had ARI scores of 0, 33.3% of the samples had ARI scores of 1, and 55.6% had ARI scores of 2, indicating that more than half of the adhesive left on the tooth.

In the SD3 group, 22.2%of the samples had ARI scores of 1 and 3, also 55,5% of the samples had ARI scores of2, indicating that more than half of the adhesive left on the tooth.

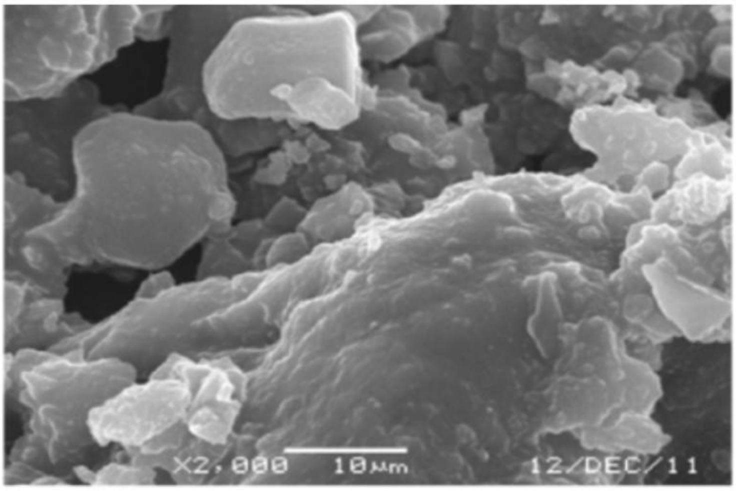
In the SD6 group showed mixed types of failure modes, No enamel fracture was noted among any samples tested on the Eplexor N500 testing machine.



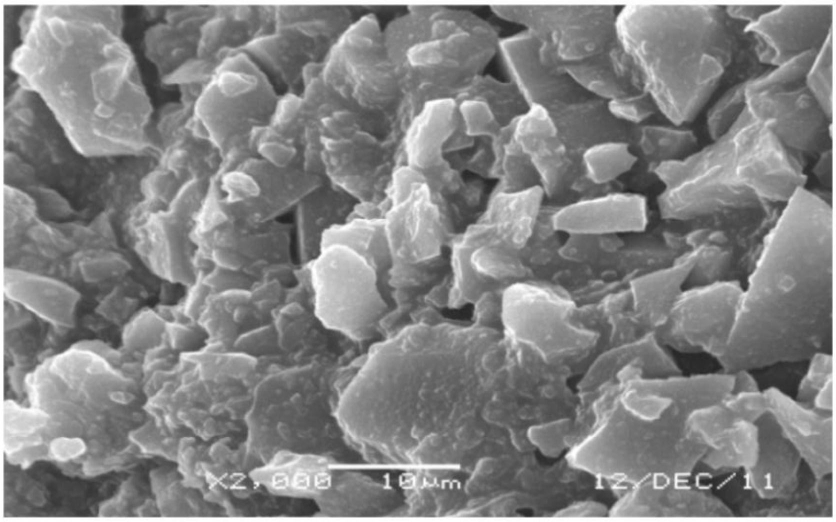
<u>Fig 5-A.</u> group SD6



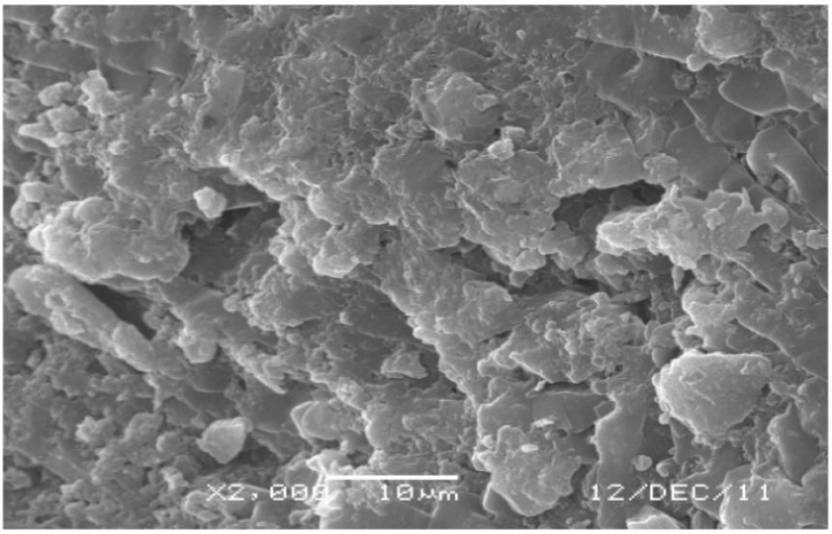
<u>Fig 5-B.</u> group SD3



<u>Fig 5-C.</u> group DD6



<u>Fig 5-D.</u> group DD3



<u>Fig 5-E.</u> group DD

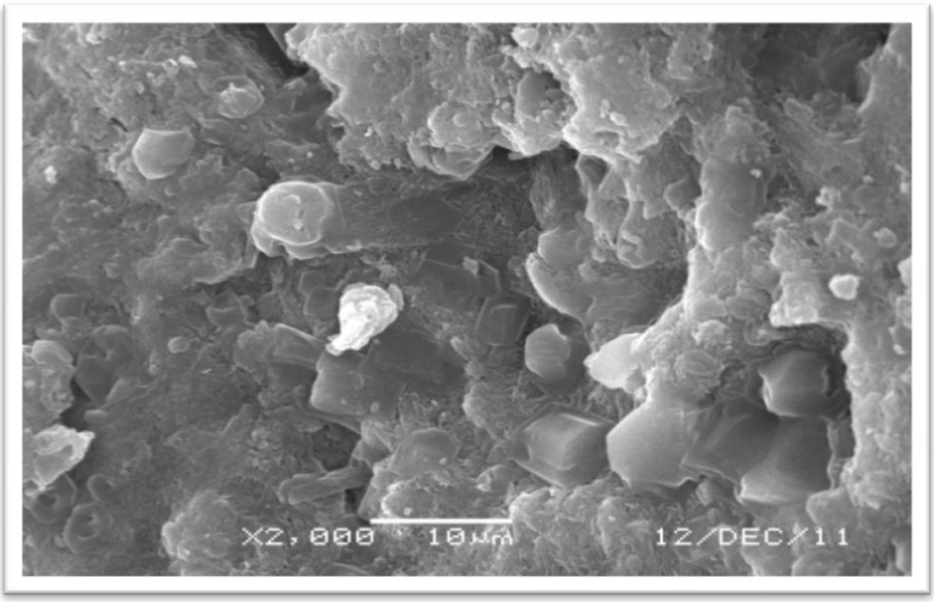


Fig 5-F. group SD

Fig 5: Scanning electron microscope (SEM) photographs of enamel surfaces after debonding in the second time. (Figure 2-A) SD6 etched with phosphoric acid for 60 second in the second bonding. (Figure 2-B) SD3 etched with phosphoric acid for 30 second in the second bonding. (Figure 2-C) DD6 etched with phosphoric acid for 60 second in the second bonding. (Figure 2-D) DD3 etched with phosphoric acid for 30 second in the second bonding. (Figure 2-E) DD with no etching in the second bonding. (Figure 2-F) SD with no etching in the second bonding.

IV. DISCUSSION

Orthodontic management procedure aim to improve recycling completely, with a short polishing stage, adhesive on the bracket base without influence on bracket mesh causing structural damage, in order to reduce or eliminate all the effects related to the orthodontic treatment, so that the bracket can be easily rebonded to enamel, producing an adequate clinical bond strength. Recycling brackets had a major advantage as reducing the economic coast [19]. On the other hand, disadvantages would be emerge as recycling brackets reducing brackets quality, removal of identification marks and of course the risk of cross-infection. An important parameter in orthodontic treatment for success treatment is bond strength. Materials like composite resins have been used to bond orthodontic brackets, composite resins are the most successful resin material [29,30]. All composite resin materials are present in the market under different brand name, almost with the same chemical composition. Different adhesive material had different shear bond strength [37,41,42].

In this study, we compared 3 orthodontic bonding systems, light cured or chemical cured composite, with a traditional and widely used clinical bonding system Transbond XT to determine whether the newer bonding systems brand demonstrate comparable bond strengths. Transbond XT is a widely used resin material by many researchers because it has excellent SBS [31,32]. The first part of our study indicated that metallic brackets bonded with Xihubiom resin material had a mean SBS of 16.99MPa and Tianjin resin16.85MPa, with no significant differences were shown between all 3 resin materials (table 3.1). Xihubiom resin and Tianjin resinhad comparable SBS with Transbond XT and clinically acceptable [28]. ARI score shows that bond failure at the enamel/adhesive interface occurred more frequently in the groups that used Xihubiom and Tianjin than in that used Transbond XT, which could be considered as an advantage during bonding/debonding metallic brackets to enamel surface. Theoretically, in-vitro studies determine the true strength of a given bonding system to the enamel substrate. An accurate simulation of the clinical situation seems necessary to obtain clinically relevant results from in vitro experiments. However, because of the many conditions involved in the in-vivo situation, an accurate simulation is at present an unrealistic goal. Although in-vitro bond strength testing is valuable for initial screening and selection of materials, it cannot be regarded as a substitute for in-vivo testing. Orthodontic materials that perform well in-vitro experiments should always be tested with in-vivo.

In the second part, our study concern about rebonding metallic brackets with Xihubiom resin. Mechanical recycling, with 7 mm space held between the bracket base and the tip of sandblaster, until all resin material was removed from the bracket base leads to a degree of metal loss in certain areas of the bracket base and creates an effective microroughened surface on the bracket base. Bond strength affected by the use of recycled or new brackets[16,40,17] Therefore, increase the area available for composite bonding in comparison to the control brackets Sonis et al. [23] found that, shear bonding strength had the same strength after debonding the second time. Seema K et al. [33] observed higher rebond strength in recycled brackets when compared with new brackets. In our study, we minimized technique inconsistencies by using the same type of brackets for all groups, standardized enamel and brackets condition, and by developing easily reproducible shear testing method. Therefore, aluminum oxide blasting groups had higher rebonded strength (RBS). In which, SD3 (13.49MPa), and SD6 (12.39MPa) groups show higher RBS values among all recycled groups which considered clinically acceptable. In contrast, many researchers used sandblasting as an in-office recycling indicated lower shear bond strengths of sandblasted compared with new brackets[26].

From the results obtained, recycled brackets with green stone DD6 (6.18MPa) and DD3 groups (7MPa) show lower strength but still clinically acceptable [44]. Therefore, Grinding brackets surface with green stone reduce shear bond strength of the brackets. Katsuyuki et al.[34] reported that adhesive left on the brackets surface, standard Metal edgewise brackets, reduce the available contact area needed between bracket base and adhesive used for rebonding. Rosenstein et al. [27] found that the adhesive left at the bracket bases reduce SBS. Aisha et al. [35] observed a significant decrease in the shear bond strength due to composite surface devoid of undercut. Mui B et al.[36] reported that using Tungsten Carbide burs for removing resin material before rebonding, produce a favorable shear bond strength and pattern of failure. However, frequency of bonding/debonding sequences [39,45] and bracket type [13,42] influence the bond strength of brackets rebonded to enamel surfaces.

In contrast to bur preparation, enamel bonding is dependent upon the infiltration of a resin material into the porosity in the surface created by acid conditioning. Because of the color similarity between present adhesives and enamel, complete removal of all remaining adhesive is not achieved easily. Many patients may be left with incomplete resin removal, which is not acceptable. Abrasive wear of present bonding resins is limited, and remnants are likely to become unaesthetically discolored with time. Therefore, the search for an efficient and safe method of adhesive resin removal following debonding has attracted the interest of many researchers, resulting in the introduction of a wide array of instruments and procedures. Conventional burs create smooth surfaces in the enamel surface. Many studies reported that reconditioning of enamel surfaces and brackets affect SBS [38,43]. In this study we found that enamel etching during the rebonding improves the shear bond strength after one hour debonding. However, the acid-etched groups was superior than non-acid etched groups, DD(4.58MPa) and SD(5.85MPa) groups with no significant difference was noted in the mean rebond strength among group [DD], and group [SD], which received enamel condition by tungsten carbide bur only. Therefore, treatment with phosphoric acid produces a repeating surface pattern, with cracks and fissures not deeper than 12 μm that are readily filled with resin [46,47]. Therefore, enamel condition with carbide bur only had the advantage of a low ARI score which compromised by lower bond strengths [48,49]. Therefore, bond failure occur more frequently at the enamel/adhesive interface. The greater strength of bonding adhesives becomes a potential problem in debonding. When a bonded bracket is removed, failure at one of the three interfaces may occur: between the bonding material and the bracket, within the bonding material itself, or between the bonding material and the enamel surface. If a strong bond to the enamel has been achieved, which is the case with the modern materials, failure at the enamel surface is undesirable, because the bonding material may tear the enamel surface as it pulls away from it. The interface between the bonding material and the bracket is the usual, and preferred, site of failure when brackets are removed. Enamel fracture have been found when the adhesion force exceeds 14 MPa,[50] and the frequency of EFs goes up with increased bond strength.[50,51] Our findings disagree with those reports, since no EFs were observed in all groups. Nonetheless, in-vitro debonding increases the frequency of EFs,[51] and orthodontists can avoid this side effect with gentler clinical debonding.[52]In addition, in-vivo bond strength has been shown to be significantly lower than the in-vitro one, suggesting thatthe frequency of EFs might be lower under clinical conditions.[53]

The reproducibility of SEM images was not high across the specimens. Therefore, and considering the subjective nature of SEM interpretations, clear-cut conclusions should not be drawn only based on these images. However, the combination of shear bond strength and SEM images might provide a more appropriate conclusion. Figure 5, which was obtained from the scanning electron microscope (SEM), shows that enamel surface became very porous, and numerous enamel crystallites and honeycomb structures were observed after phosphoric acid etching. Gardner et al. [54]stated that the use of 37% phosphoric acid with a 30 second etch time has been confirmed as a sensible routine choice for routine orthodontic bonding. Ali Obeidi et al [55] reported that 60 seconds acid etching may degrade the shear bond strength of the composite resin to the enamel. Figure 5, shows that a greater number of porosities were observed on the enamel surface re-etched with 30 second as in SD3, DD3 groups. These SEM findings could verify our results that DD and SD groups had significantly lower mean rebonded shear bond strength than other groups.

V. CONCLUSION

In this in-vitro study, we found the following:

1) The shear bond values of 3 adhesives are clinically acceptable, and orthodontic brackets can be successfully bonded with any of these resin brands.
2) We recommend the use of Xihubiom resin for bonding and rebonding brackets. for economic saving.
3) Recycling brackets base with 50 μm aluminum oxide sandblasting and enamel etching for 30 seconds had the best rebonding strength when compared to green stone treated brackets base.
4) In the second debonding after cementationone hour later, enamel re-condition with tungsten Carbide bur only is insufficient as a conditioning procedure but, if combination with acid etching, reasonable rebonding strength can be achieved.

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