***ISSN:* 1812–1217**

Assessment of Shear Bond and Failure Surface of Bonded and Rebonded Brackets Using Conventional Acid and Micro-etching Techniques

Mustafa M Hamed
BDS, MSc (Assist Lect)

Dept of Pedod, Orthod, and Prev Dentistry
College of Dentistry, University of Mosul

الخلاصة

الأهداف: الكشف ألمختبري لمقارنة معدل قوة الالتصاق ومقياس كمية المادة اللاصقة للحواصر المعدنية الجديدة والمعادة باستخدام الطريقة التقليدية والحديثة لتحضير السن. **المواد والطرق:** الأوجه الخدية التابعة لأربعين ضرس ضاحك بشري عولجت بالطريقة الحديثة لتحضير المينة لمدة 5 ثواني باستخدام جزيئات الالومينا 50 ماكرون عن بعد 4 ملم ونفس العدد من الأسنان عولجت بحامض الفسفوريك 37% لمدة 20 ثانية بعد حضانة لمدة 24 ساعة بدرجة حرارة 37 سيليزية في ماء مقطر، بعدها كل مجموعة قسمت إلى أربعة مجاميع ثانوية كل مجموعة ثانوية مكونة من 10 أسنان، تم قياس قوة الالتصاق ونوع فشل المادة اللاصقة للحواصر الجديدة والمعادة باستخدام جهاز فحص قوة الشد العالمي مع مقطع راسي بسرعة 10 ملم لكل دقيقة. **النتائج:** معدل قوة الالتصاق كانت بصورة معنوية اقل للحواصر الملصقة للمينة المعاملة بالطريقة الحديثة بالمقارنة بالطريقة التقليدية، نفس النتائج تم الحصول عليها بالنسبة للحواصر المعادة، ولوحظ ان اقل قوة التصاق رافقت الطريقة الحديثة لمعاملة المينة باستخدام حواصر جديدة ومعادة وبينما أعلى قوة التصاق كانت للحواصر الملصقة بالمينة المعاملة بالطريقة التقليدية بالنسبة للحواصر الجديدة والمعادة بالنسبة لبقايا المادة الملتصقة على سطح المينة فأن احتمالية بقائها تكون اقل من ماهي عليه في المينة المعاملة بالطريقة الحديثة والعكس بالنسبة للمينة المعاملة بالطريقة الحديثة مهما كانت طريقة المعاملة الأولى.الحواصر الملصقة بالمينة المعاملة بالصورة التقليدية تشهد نوعية من فشل المادة اللاصقة وهو الفشل ألتماسكي والتلاصقي للمادة أما بالنسبة للمينة المعاملة بالطريقة الحديثة فتشهد فشل تلاصقي. **الاستنتاج:** مهما كانت المرحلة الأولى من المعاملة، أعلى قوة التصاق في المرحلة الثانية بالمعاملة التقليدية للمينة باستخدام حواصر جديدة ومعادة. أما بالنسبة للحالات التي عولجت بالطريقة التقليدية في المرحلة الأولى والحديثة في المرحلة الثانية أعطتنا قوة التصاق مناسبة حصرا مع الحواصر الجديدة.

ABSTRACT

Aims: To compare the mean shear bonding force and mode of bond failure of metallic brackets bonded and rebounded (using new and pre-used brackets) to sandblasted and acid-etched enamel is described. **Materials and methods:** The buccal surfaces of 40 extracted human premolars were sandblasted for 5 seconds with 50 µ alumina at 4mm distance and the buccal surfaces of a further 40 human premolars were acid etched with 37% phosphoric acid for 20 seconds. Following storage for 24 hours at 37°C in distilled water, then each group was divided into four subgroups of ten teeth, shear bonding force and the bond failure were measured for bonded and rebounded new and pre-used brackets using a Universal Testing Machine with a cross-head speed of 10 mm/minute. **Results:** The mean shear debonding force was significantly lower for brackets bonded to sandblasted enamel compared to acid etched enamel ($P < 0.000$), the same thing for the rebounded brackets, with the lowest shear bonding forces for brackets bonded to sandblasted enamel in the first and second step while the shear bond strength was higher for brackets bonded to acid etched enamel what ever the first treatment of enamel weither conventional acid etching or microetching. Statistical analysis showed that at a given stress the probability of failure was significantly greater for brackets bonded to sandblasted enamel. This is in the first step, the same thing in the second step was greater probability of bond failure for enamel treated in the first and second step with Microetcing and still greater in teeth treated with Microetching opposite to that is for teeth treated in second step with acid etching and the significantly lower probability of bond failure for brackets bonded to acid etched enamel in first and second step. Brackets bonded to acid etched enamel showed a mixed mode of bond failure (adhesive and cohesive failure) , whereas following sandblasting, failure was adhesive at the enamel/composite interface ($p \leq 0.000$). **Conclusions:** Whatever the first step of treatment, higher shear bond in the second step could be obtained using acid etching with new and old brackets, but in cases treated with acid etching in first step and microetching in second step a suitable shear bond strength could be obtained insist with new brackets.

Key Words: Shear bond, failure surface, bonded and rebounded brackets.

Hamed MM. Assessment of Shear Bond and Failure Surface of Bonded and Rebonded Brackets Using Conventional Acid and Micro-etching Techniques. *Al–Rafidain Dent J*. 2010; 10(1): 110-118.
Received: 17/9/2008 ***Sent to Referees:*** 22/9/2008 ***Accepted for Publication:*** 21/12/2008

INTRODUCTION

Direct bonding of brackets and other attachments with composite resins have become a routine technique in fixed orthodontic treatment(1). Since the work of Newman (1965) as cited by Sargison *et* *al*.,[2] orthodontic brackets have been bonded to teeth with resin adhesives following enamel pretreatment with acid. However, the acid etch technique has several undesirable sequel. These include loss of enamel, cracks and scratches due to etching, debonding, and clean up and retention of resin tags or indelible staining[3]. A further disadvantage is the difficulty in confining the etchant to the area covered by the bracket base. To overcome some problems presented by the acid etch technique, sandblasting technique has been investigated. This technique has been used in orthodontics for treating the fitting surfaces of bands and brackets to enhance bond strength[4] and for the removal of cement from failed brackets prior to recementation[5]. Several studies[6-8] have to date evaluated sandblasting as a method of enamel preparation prior to bracket bonding. Within the development of miniature intra-oral sandblasters, it would seem timely to explore this possibility further.

Many researchers have investigated the effects of sandblasting[9-12]. Some researcher [9-11,13] preferred the use of sandblasting to increase surface roughness of non-enamel surfaces (metal, gold, amalgam, or porcelain), while others[12] suggested that direct sandblasting may be a feasible method for preparing teeth for orthodontic bonding. Clinicians may face problem during treatment is the bracket failure. In a busy orthodontic practice, a significant number of teeth will need to be rebonded.

This study was conducted to determine the mean shear bonding force of orthodontic brackets following enamel preparation with either sandblasting or etching and to detect the best method of enamel preparation providing a suitable shear bond strength and bond failure for bonding and rebonding (new/ pre-used) orthodontic brackets. Finally, to analyze the mode of bond failure with both methods of enamel preparation.

MATERIALS AND METHODS

Eighty extracted human premolars were collected after their extraction for orthodontic purposes and stored in a distilled water at 37°C following decontamination in formalin. They were divided onto two groups of 40 premolars. The criteria for tooth selection included intact buccal enamel, no cracks caused by the extraction forceps, and no defects. The teeth were cleansed and polished with pumice and rubber prophylactic cups for ten seconds. Dentarum (Dentarum, Pforzheim, Germany) standard edgewise orthodontic metal brackets were used in this study. The average bracket base surface area was determined to be 10.64 mm^2. The roots of teeth were grooved to aid retention and then mounted in stone blocks with their long axes vertical and their crowns protruding. The buccal enamel surfaces were cleaned with a pumice slurry for ten seconds, washed in water for ten seconds and dried. The teeth then subjected to two steps these includes:

Step I: Involves the following procedures:

1. Etching: the buccal surfaces of 40 teeth were etched with 37 per cent phosphoric acid solution for 20 seconds, washed for ten second, and dried thoroughly for fifteen seconds[15].
2. Sandblasting: the buccal surfaces of 40 teeth were sandblasted with a micro-etcher (DANVILLE Materials Innovative Dental Product) using 50 µm (Recommended by the manufacture) alumina for 5 seconds at a distance of 4mm and then blown with air to remove any residual contamination[2]. In relation to the duration, because of no difference was noted under scanning electron microscope between enamel sand-blasted for 5, 15, 30, 45, or 60 seconds as stated by Sargison *et al*.,[2]. So a 5-second sandblast would be the only reasonable duration clinically, as a result, this time interval was chosen for specimen preparation.

The prepared middle part of the middle third of the buccal surfaces of premolars were bonded with metal brackets using a light cured composite resin (Tetric version, Ivoclar Vivadent). A 200 gram load were applied on each bracket using simple surveyor with slight modification were the cutted end of the surveyor blade seated in the bracket slot for loading and the excess composite was removed with a probe; then were immersed in distilled water at 37°C for 24 hours. The shear debonding force required to debond the brackets was measured in Newtons using a cross-head speed of 10 mm/minute then the force measured converted to mega pascal (MPa). After being debonded, the teeth and brackets were examined under 10X magnification Microscope. Any adhesive remaining after bracket removal was assessed according to the modified adhesive remnant index (ARI) and scored with respect to the amount of resin material that adhered to the Bracket base[16].

The criteria for evaluation were: The ARI scale has a range of 5 to 1 score according to the amount of adhesive remain on the bracket base Score 5=no composite; score 4=less than 10% of composite remained; score 3=more than 10% but less than 90% of the composite remained; score 2=more than 90% of the composite remained; score 1=all of the composite remained).

Step II: In this step, the whole remaining adhesive on the buccal surfaces of the premolars were removed with carbide bur using high speed hand piece with cooling then polished with fluoride free pumice, washed with water and dried. Each group then subdivided into 4 subgroups of ten teeth and treated according to the following procedures with notation that the adhesive used in the second step is the same as that used in the first step:

I. The first Acid Etched group composed of the following subgroups:

A. The first subgroup (AAN): The previously acid etched group subjected to the acid etching and bonded with new brackets.

B. The second subgroup (AAR): The previously acid etched group subjected to acid etching and bonded with re-used bracket (after their cleaning with carbide bur using high speed hand piece with cooling).

C. The third subgroup (AMN): The previously acid etched group subjected to micro-etching with 50µ aluminum oxide for 5 second, 4mm distance and bonded with new brackets.

D. The fourth subgroup (AMR): The previously acid etched group subjected to micro-etching with 50µ aluminum oxide for 5 second, 4 mm distance and bonded with re-used bracket (after their cleaning with carbide bur using high speed hand piece with cooling).

II. The second Micro-etched group composed of the following subgroups:

E. The first subgroup (MMN): The previously Micro-etched group subjected to Micro-etching with 50µ aluminum oxide for 5 second, 4 mm distance and bonded with new brackets.

F. The second subgroup (MMR): The previously Micro-etched group subjected to Micro-etching with 50µ aluminum oxide for 5 second, 4 mm distance and bonded with re-used bracket (after their cleaning with carbide bur using high speed hand piece with cooling).

G. The third subgroup (MAN): The previously Micro-etched group subjected to acid etching and bonded with new brackets.

H. The fourth subgroup (MAR): The previously Micro-etched group subjected to acid etching and bonded with re-used bracket (after their cleaning with carbide bur using high speed hand piece with cooling).

Shear bond strengths were measured at a crosshead speed of 5 mm/min. After being debonded, the teeth and brackets were examined under 10X magnification Microscope. Any adhesive remaining after bracket removal was assessed according to the modified adhesive remnant index (ARI) assigned above and scored with respect to the amount of resin material that adhered to the bracket base.

Descriptive statistics that included the mean, standard deviation, and minimum and maximum values were calculated for each tested groups and subgroups. The student *t* test was used to determine whether significant differences were present in the bond strength between the two groups. One way ANOVA and Duncan methods were used to detect the significance of difference within each group. The chi-squared test was also used to determine significant differences in the ARI scores between and within group. Significance for all statistical tests was predetermined at a probability value of ($p \leq 0.001$).

RESULTS AND DISCUSSION

Acid etching results in chemical changes that may produce modification of the organic material and decalcification of the inorganic component of enamel[17,18]. Acid etching is a form of microetching, whereas sandblasting can be regarded as a form of macroetching. Chung *et al.*,[12] used sandblasting to remove unfavourable oxides and contaminants and increase surface roughness promoting a convenient surface for bonding. In the present study, sandblasting was applied to the enamel surface to test whether it was capable of producing etching patterns suitable for bonding.

The sandblasting of enamel displayed obtuse angularities instead of the sharp irregularities of etched enamel surfaces which could lead to weak bond strengths[19, 20].

As shown in Table (1), for the first step, sandblasting of the enamel showed a lower shear bond than clinically acceptable limits. It has been shown that sandblasting be helpful to increase bond strengths on porcelain or amalgam surfaces[9, 10, 19]. In another study by Reynolds and Von Frauenhofer[23], minimum bond strength of 5.9 to 7.8 MPa was found adequate for most clinical orthodontic needs. Furthermore, the shear bond strength recommended for successful clinical bonding was estimated to be 7 MPa by Lopez[24].

The mean shear debonding force for brackets bonded following 20 seconds etching was significantly greater than for 5 seconds sandblasting as illustrated in Tables (2 and 3). Several factors may account for this difference.

Acid etching provides micromechanical attachment by a variety of means, ranging from preferential dissolution of the prism cores to preferential dissolution of the prism peripheries[25]. The preferential dissolution of the prisms can occur to a depth of 5–25 µ with the diameter of the defect ranging from 5–6 µ[23].

In relation to sandblasting, a uniform roughness of the enamel up to 5 µ in depth are resulted[26], so that a difference could be seen in depth of the undercut and this could be one of the important factor that contributing to the difference in shear bond strength, as increasing depth will lead to increasing strength.

Table (1): Descriptive statistics of shear bond strength for microetching and acidetching groups.

Groups	Number	Minimum	Maximum	Mean	$\pm$ SD
Microetching	40	3.450	7.640	5.268	1.008131
Etching	40	8.985	15.160	11.978	1.469164

SD: Standard deviation.

Table (2): Descriptive statistics of shear bond strength for the subgroups of the microetching and acidetching groups.

Subgroups	Number	Minimum	Maximum	Mean	± SD
MMN	10	3.980	5.840	4.89760	0.665258
MMR	10	2.780	5.054	4.14110	0.717334
MAN	10	10.893	14.651	12.55440	1.108032
MAR	10	8.519	11.834	10.08790	1.043050
AAN	10	12.450	16.010	14.60500	1.064168
AAR	10	9.231	13.483	12.18680	1.361604
AMN	10	5.360	9.070	7.31220	1.128707
AMR	10	4.130	7.054	5.14630	0.914670

SD: Standard deviation. MMN: Previously Microetched teeth subjected to Micro-etching using new brackets; MMR: Previously Microetched teeth subjected to Micro-etching using pre-used bracket; MAN: Previously Microetched teeth subjected to acid etching using new brackets; MAR: Previously Microetched teeth subjected to acid etching using pre-used bracket; AAN: Previously acid etched teeth subjected to acid etching using new brackets; AAR: Previously acid etched teeth subjected to acid etching using pre-used bracket; AMN: Previously acid etched teeth subjected to micro-etching using new brackets;ANR: Previously acid etched teeth subjected to micro-etching using pre-used bracket.

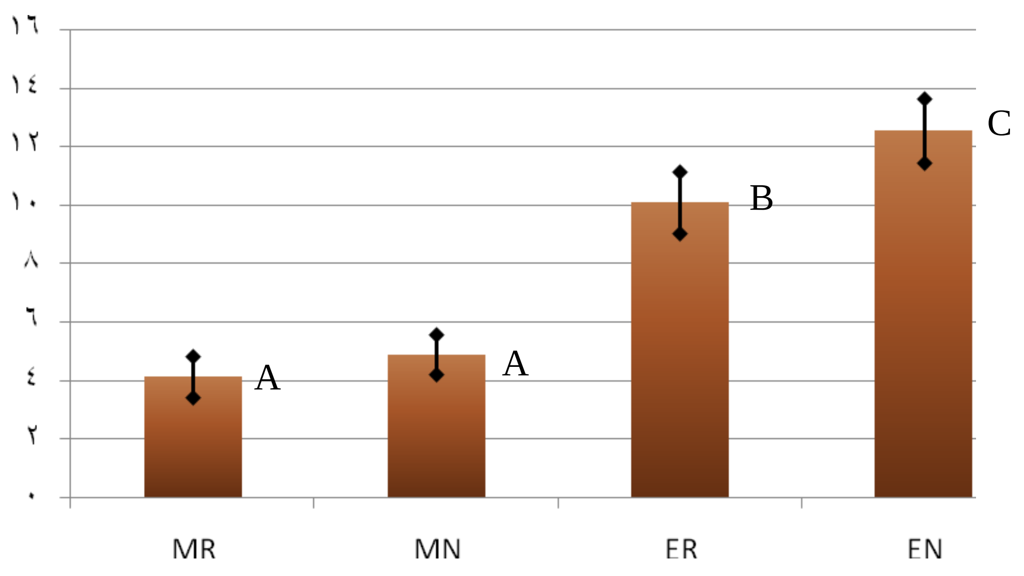
Table (3): Independent Sample t–Test.

***t*-test for Equality of Means**			
***p*–value**	**df**	**T**	
0.000	78	–23.821	**Shear Bond Strength**

As shown in the Table (2) For the rebond step, the shear debonding forces of the 8 subgroups shows a great varieties of results range from the highest mean for (AAN) subgroup (The previously acid etched group subjected to the acid etching and bonded with new brackets) to the lowest readings for (MMR) subgroup (The previously Micro-etched group subjected to Micro-etching with 50µ aluminum oxide for 5 second, 4 mm distance and bonded with re-used bracket), with the significant differences between and within group as shown in Table (4), further explanation for that the shear debond strength tend to be increased in cases were retreated with conventional acid etching, whatever the first treatment of enamel whatever conventional acid etching or micro-etching, this may be attributed to increasing depth of resin tag associated with the conventional etching as compared with Micro-etching, with the highest reading presented in cases that were first and second treated with conventional acid etching, and tend to be lowered in cases that were retreated with Micro-etching with the lowest mean in cases that were first treated with Micro-etching Figures (1 and 2).

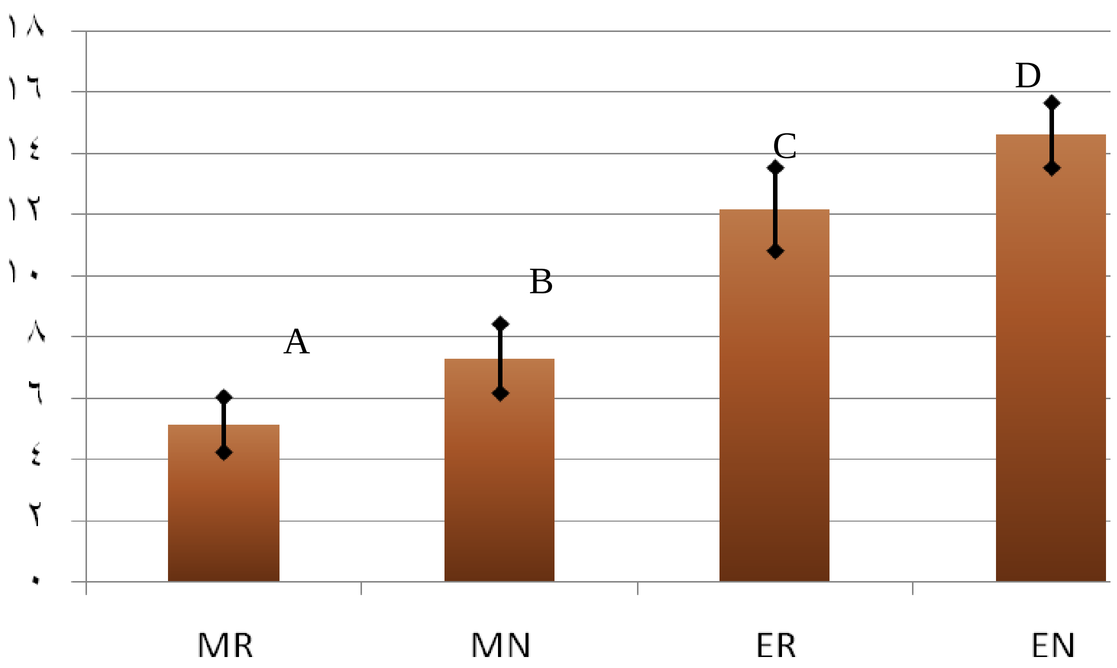
Table (4): One Way ANOVA.

		Sum of Squares	df	Mean Square	F–value	*p*–value
Shear Bond Strength Microetch	**Between Groups**	495.924	3	165.308	202.037	0.000
	Within Group	29.455	36	0.818		
	Total	525.380	39			
Shear Bond Strength Acidetch	**Between Groups**	566.303	3	188.768	148.140	0.000
	Within Group	45.873	36	1.274		
	Total	612.176	39			



Means with the same letter were statistically not significant ($p > 0.05$).

Figure (1): Means ± standard deviation of the shear bond strength for the subgroups of Microetching and Duncan's Multiple Range test.



Means with the same letter were statistically not significant ($p > 0.05$).

Figure (2): Means ± standard deviation of the shear bond strength for the subgroups of etching and Duncan's Multiple Range test.

For the mode of bond failure, as shown in Table (5) significant differences presented between Microetched and acid etched groups in that, the brackets bonded to sandblasted enamel showed less composite remaining on the enamel surface than with acid etching (adhesive failure).

Although this mode of bond failure would facilitate clean up following debonding and reduce the possibility of iatrogenic damage to enamel following this procedure, the weak bond strengths recorded with sandblasting enamel precludes its use clinically. So probably a suitable shear bond strength for orthodontic attachment using sandblast may be obtained either by increasing size of aluminum oxide particle or by decreasing distance between the tip of Microetcher and the enamel surface.

In the second step the mode of bond failure, as shown in Table (5), a significant differences were estimated between the subgroups in each group in that the subgroup subjected to acid etching in the first and second step showing mainly adhesive failure with 4 and 5 scores which means that composite mainly attached to enamel due to high bond strength associated with acid etching, with larger number of score 5 to score 4 in (AAN) subgroups further we noted that there were 3 reading of score 3 in the same subgroup and this is may be due to the use of new brackets that increase bonding strength to new mesh base but for (AAR) subgroup (The previously acid etched group subjected to acid etching and bonded with re-used bracket) the only one reading of score 3 probably be the result of weak bond between new and remaining few old composite attached to bracket base or it may be uncontrolled contamination.

Table (5): Mode of bond failure for the subgroups of both etching techniques.

Acid-etch				**Micro–etch**				**Scores**
MR	**MN**	**AR**	**AN**	**MR**	**MN**	**AR**	**AN**	
1	7	0	0	4	8	0	0	**1**
4	2	0	0	3	2	0	0	**2**
5	1	1	3	3	0	1	3	**3**
0	0	7	4	0	0	4	4	**4**
0	0	2	3	0	0	5	3	**5**
Chi square= 29.37, df= 3; *p*= 0.000, Significant				Chi square= 30.39, df= 3; *p*= 0.000, Significant				**Kruskal–Wallis Test**
Z= 4.472; D (absolute)= 1.000, *p*= 0.000, Significant								**Kolmogorov–Smirnov Test**

AN: Teeth subjected to acid etching in the next step using new brackets; AR: Teeth subjected to acid etching in the next step using pre-used bracket; MN: Teeth subjected to Micro-etching in the next step using new brackets; MR: Teeth subjected to Micro-etching in the next step using pre-used bracket; AN: Teeth subjected to acid etching in the next step using new brackets; AR: Teeth subjected to acid etching in the next step using pre-used bracket; MN: Teeth subjected to micro-etching in the next step using new brackets; NR: Teeth subjected to micro-etching in the next step using pre-used bracket; 5=no composite; 4=less than 10% of composite remained; 3=more than 10% but less than 90% of the composite remained; 2=more than 90% of the composite remained; 1=all of the composite remained.

For the subgroups retreated with Microetching (with the acid etching in the first step) showed different results, the larger number of score 1 in (AMN) subgroup (The previously acid etched group subjected to micro-etching with 50µ aluminum oxide for 5 second, 4 mm distance and bonded with new brackets). Already may be due to stronger composite bond to the new bracket base against the weak bond to Microetched enamel but for (AMR) subgroup (The previously acid etched group subjected to micro-etching with 50µ aluminum oxide for 5 second, 4 mm distance and bonded with re-used bracket) here we have pre-used brackets and Microetched enamel with old resin tags (the result of 1st acid etch treatment) that increase the probability of cohesive failure and this could be postulated by a lot off reading of score 3.

For the subgroups that 1st treated with Microetching then retreated with Acid etching here the probability of score 4 and 5 increased because of strong bond of composite to acid etched enamel whatever the brackets new or old although the new bracket showed tendency for increasing adhesion to composite due to good mechanical lock and these could be explained by the three reading of score 3 in (MAN) subgroup(The previously Micro-etched group subjected to acid etching and bonded with new brackets).

For subgroup treated by Microetching in the 1st and 2nd step, as presented in the table for (MMN) subgroup (The previously Micro-etched group subjected to Microetching with 50µ aluminum oxide for 5 second, 4 mm distance and bonded with new brackets) a higher number of score 1 because stronger mechanical bond to the new mesh base compared to Microetched enamel, for the (MMR) subgroup we see number of score 2 and 3 reading which are due to cohesive failure between new and few old composite.

CONCLUSIONS

Higher shear bonding force with 20 second acid etching than 5 second microetching were as a significantly less probability of bond failure for acid etching compared to micro-etching. Brackets bonded to etched enamel showed a mixed mode of bond failure whereas following sandblasting; failure was adhesive at the enamel/ composite interface. From this study, the main disadvantages of sandblasting enamel were the unacceptably low bonding force in comparison to acid etching, sandblasting enamel is not recommended as a means of enamel preparation for orthodontic bonding but from the mode of bond failure it is considered as suitable means of etching for orthodontic bonding. From the result of statistical analysis a conclusion could be drawn that what ever the first step of enamel treatment a good bonding strength could be obtained in the second step using acid etching with new or old brackets but in cases first treated with acid etching in the second step Microetching technique could be used insist with new bracket.

REFERENCES

1. Silverman E, Cohen M, Gianelly AA, Dietz VS. A universal direct bonding system for both metal and plastic brackets. *Am J Orthod*. 1972; 62: 236–244.
2. Sargison AE, Mccabe JF, Millett DT. A Laboratory Investigation to Compare Enamel Preparation by Sandblasting or Acid Etching Prior to Bracket Bonding. *British J Orthod*. 1999; 26: 141–146.
3. Evans R, Oliver R. Orthodontic bonding using glass ionomer cements: an in-vitro study. *Europ J Orthod*. 1991; 13: 493–500.
4. Millett DT, McCabe JF, Gordon PH. The role of sandblasting on the retention of metallic brackets applied with glass ionomer cement. *British J Orthod*. 1993; 20 :117–122.
5. Regan D, LeMasney B, Van-Noort R. The tensile bond strength of new and rebonded stainless steel orthodontic brackets. *Europ J Orthod*. 1993; 15 :125–135.
6. Reisner KR, Levitt HL, Mante F. Enamel preparation for orthodontic bonding: a comparison between the use of a sandblaster and current techniques. *Am J Orthod Dentofacial Orthop*. 1997; 111: 366–373.
7. Olsen ME, Bishara SE, Damon P, Jakobsen JR. Comparison of shear bond strength and surface structure between conventional acid etching and air-abrasion of human enamel. *Am J Orthod Dentofacial Orthop* 1998; 113(5): 20A-22A.
8. Waveren HWL, Feilzer AL, Prahl B. The air-abrasion technique versus the conventional acid-etching technique: a quantification of the surface enamel loss and comparison of shear bond strength. *Am J Orthod Dentofacial Orthop*. 2000; 117: 20–26.
9. Zachrisson BU, Büyüky lmaz T, Zachrisson YØ. Improving orthodontic bonding to silver amalgam. *Angle Orthod*. 1995; 65 : 35–42.
10. Miller S, Zernik JH. Sandblasting of bands to increase bond strength. *J Clinic Orthod*. 1996; 30 : 217–222
11. Chung KH, Hwang YC. Bonding strengths of porcelain repair systems with various surface treatments. *J Prosth Dent*. 1997; 78 : 267–274.
12. Chung K, Hsu B, Berry T Hsieh T. Effect

of sandblasting on the bond strength of the bondable molar tube bracket. *J Oral Rehabilitation*. 2001; 28 : 418–424.
13. Büyüky lmaz T, Zachrisson Y Ø, Zachrisson BU. Improving orthodontic bonding to gold alloy. *Am J Orthod Dentofacial Orthop*. 1995; 108 : 510 –518.
14. Miller S, Zernik JH. Sandblasting of bands to increase bond strength. *J Clinic Orthod*. 1996; 30 : 217–222.
15. Hassan Z, Movahhed BG, Morten S. An in vitro comparison of the shear bond strength of a resin-reinforced glass ionomer cement and a composite adhesive for bonding orthodontic brackets. *Europ J Orthod*. 2005; 27: 477–483.
16. Oilver RG. The effect of different methods of bracket removal on the amount of residual adhesive. *Am J Orthod Dentofacial Orthop*. 1988; 93: 196–200.
17. Bertolotti RL. Conditioning of the dentin substrate. *Operat Dent Suppl*. 1992; 5 : 131–137.
18. Pashley DH. The effects of acid etching on the pulpodentin complex. *Operat Dent*. 1992; 17 : 229–234.
19. Zachrisson BU Buyukyilmaz T. Recent advances in bonding to gold, amalgam and porcelain. *J Clinic Orthod*. 1993; 27: 661–675.
20. Millett DT, McCabe J F, Bennett TG, Carter NE, Gordon PH. The effect of sandblasting on retention of first molars orthodontic bands cemented with glass ionomer cement. *Brit J Orthod*. 1995; 22 : 161–169.
21. Bishara SE, Gordan VV, Von WL, Olson ME. Effect of an acidic primer on shear bond strength of orthodontic brackets. *Am J Orthod Dentofacial Orthop*. 1998; 114: 243-247
22. Wheeler JJ, Ackerman JRJ. Bond strength of thermally recycled metal brackets. *Am J Orthod*. 1983; 88: 181–186.
23. Reynolds IR, Von FJA. Direct bonding of orthodontic attachments to teeth: the relation of adhesive bond strength to gauze mesh size. *Brit J Orthod*. 1976; 3: 91–95.
24. Lopez JI. Retentive shear strengths of various bonding attachment bases. *Am J Orthod*. 1980; 77: 669–678.
25. Carstensen W. The effect of different phosphoric acid concentrations on surface enamel. *Angle Orthod*. 1992; 61: 51–57.
26. Laurell K L, Hess JA. Scanning electron micrographic effects of air-abrasion cavity preparation on human enamel and dentin. *Quint Internat*. 1995; 26: 139–144.