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In vitro Evaluation of Shear Bond Strength of New and Rebonded Brackets Reconditioned with Grinding: Effect of ARI Index

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Abstract: The aim of the current study was to compare the rebond strength of the high ARI index brackets with that of the low ARI index and also with the new brackets. Initially, 150 new brackets were gathered and underwent a bonding/rebonding procedure on human premolar teeth to achieve various ARI indices. The brackets were then rebonded (on 3 sets of 20 new human premolar teeth) as group A: brackets with ARI score above IV (i.e., IV^+) ; group B: brackets with ARI score below II (i.e., II^-); group C: brackets with ARI score III. Group D (control group) included another twenty premolar teeth which were bonded with new brackets. The bond strengths were evaluated using ANOVA analysis and Tukey follow up test under SPSS. Statistical significance was set at $p<0.05$. The ANOVA analysis indicated that ARI score IV^+ brackets (group A) and also new brackets (group D) had significantly a higher rebond strength (13.98 and 15.67 Mpa, respectively) than those of ARI score II^- (8.05 Mpa) and score III (9 Mpa) brackets ($p<0.05$). However, no statistically significant difference existed between control and ARI score IV^+ group ($p>0.05$). The findings indicated that score IV and V brackets had a higher rebond strength than score I-III brackets. Furthermore, score IV and V brackets had a comparable rebond strength with new brackets. However, as with any laboratory study, caution should be taken in extrapolating these findings to oral environment.

Key words: ARI index, rebonding, bracket reconditioning, extrapolating, ANOVA analysis

INTRODUCTION

One of the most common clinical problems encountered in the orthodontic treatments is the accidental dislodgment of brackets. Rebonding these loose brackets require clinical chair time and is a nuisance in the course of orthodontic treatment. Bracket loosening occurs due to a variety of reasons ranging from biting trauma to inappropriate bonding technique. Epidemiologically, the prevalence of accidental debonding ranges from 3.5-23%. When confronting a loose bracket, several things should be considered before rebonding (Mui *et al*., 1999):

- Enamel reconditioning
- Choosing between new or original (debonded) brackets
- Using of bonding material

The bond strength of brackets should be in a range which resist every day biting forces but does not cause enamel damage in the final debonding session. Optimal bond strength has been reported to be 6-8 Mpa (Keizer *et al*., 1976; Akin-Nergiz *et al*., 1996). However, no consensus has been achieved in the literature as to the comparison of the bond strength between rebonded brackets and brackets bonded for the first time. Some studies have proposed higher bond strength for rebonded brackets (Eminkahyagil *et al*., 2006), some suggested a comparable value (Montasser *et al*., 2008) and some showed a lower value for the rebonded brackets. (Jassem *et al*., 1981; Bishara *et al*., 2000).

These differences have been attributed to several reasons ranging from difference in reconditioning methods (Basudan and Al-Emran, 2001; Chung *et al*., 2002) difference in the remaining adhesive on the bracket base and also the type of brackets (Willems *et al*.,1997).

Several methods have been proposed in the literature for reconditioning the bracket bases for rebonding purposes. Sand blasting (Tavares *et al*., 2006), laser treatment (Ishida *et al*., 2011) microetching (Eminkahyagil *et al*., 2006) and also industrial recycling of brackets (Graber *et al*., 2011) are among the proposed techniques. Almost all of these techniques rely with varying degrees on increasing the mechanical retention between bracket base and composite resin. On the other hand, large scale use of the previously described methods for recycling brackets has been limited because of reasons like high cost or consumption of great deal of time. One of the differences between the current study with the

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previous studies is the method for reconditioning of brackets. In the current study, a slight grinding of bracket bases was used.

In almost all of the studies regarding bracket failure, adhesive remnant index has been a major component. However, as for rebonding purposes of brackets with different ARI indices, to the researchers' knowledge till far, no study has systematically investigated the matter. Considering the need for a favorable Cost-Effective Method for rebonding brackets with adequate bond strength and acceptable clinical chair time and taking into account the adhesive remnant index of brackets, a need for a new study is felt. Therefore, the aim of the current study was to compare the rebond strength of high ARI index brackets (score IV, V) with low ARI index brackets (score I-III) and also new brackets rebonded with a grinding technique.

MATERIALS AND METHODS

The research protocol comprised of four stages: initial bonding, initial debonding, rebonding and second debonding. The objective of the two initial bonding, debonding processes was to achieve the various ARI indices while the aim of the third and fourth stages was to compare the rebond strengths.

Initial bonding: Initially, in order to gather the target population of brackets with various ARI indices, an arbitrary 150 premolar bracket of Standard 18 Slot type, (Equilibium, Dentaarum Inc., Germany) were collected and underwent an initial bonding/debonding process on extracted human premolar teeth. The teeth were extracted for reasons other than purposes of this study. In the visual examination, the teeth should not have had any sort of caries, crack, restorative material, abrasion or any sort of structural deficit. The teeth were cleaned and stored in 0.1% thymol solution at room temperature for a week before bonding. The buccal surfaces of the teeth were etched with liquid 37% phosphoric acid (Reliance orthodontic products, Illinois, USA) for 30 sec and then bonded with a no-mix adhesive paste (Reliance orthodontic products, Illinois, USA) as per instructions of the company. A constant force of 200 g was applied to brackets by gauge for 10 sec to achieve an even layer of adhesive.

Initial debonding: After the initial bonding was completed, the teeth were then put on 37°C distilled water for 24 h after which the initial debonding was performed by a debonding plier (346ETM Corp., California, USA) connected to the Universal Testing Machine (Hunsfield test equipment HSK) with a cross head speed of 0.5 mm sec^{-1} (Fig. 1). At this stage, the debonded brackets were examined to determine their respective ARI indices by an optical stereo microscope (Olympus S2x9, Tokyo, Japan) under x10 magnification. ARI index was categorized by the following nomenclature, per the reference study (Oliver, 1988):

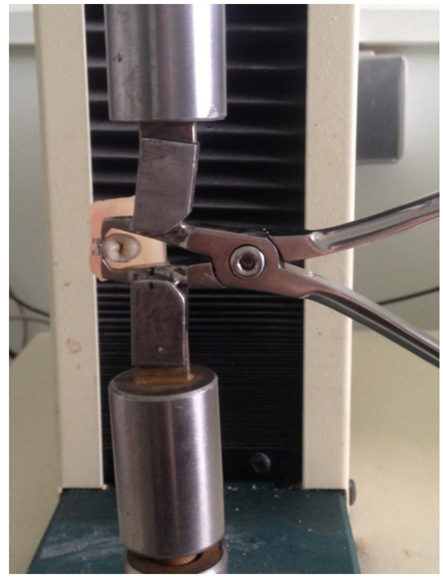

Fig. 1: A sample bracket in the Hunsfield test equipment machine

- Score 5: no adhesive is remaining on enamel, i.e., all adhesive is on bracket surface
- Score 4: <10% adhesive is remaining on enamel, i.e., >90% of adhesive is on bracket base
- Score 3: 10-90% of adhesive is remaining on enamel
- Score 2: >90% of adhesive is remaining on enamel, i.e., <10% adhesive remains bracket
- Score 1: all the adhesive is remaining on enamel

The brackets were allocated into 3 groups of twenty brackets plus a control group of same quantity, according to following:

- Group A: ARI index above score IV (IV^+, i.e., IV and V)
- Group B: ARI index below score II (II, $^-$i.e., II and I)
- Group C: ARI index score III
- Group D: a total of 20 new brackets from the same commercial type which did not go under initial bonding/debonding

Rebonding: After determining the ARI indices and allocating the brackets to 4 groups, the first three groups (A-C) were rebonded to 3 groups of twenty newly allocated human premolars. They were rebonded by the following method. The composite adhesive resins on the bracket bases were lightly ground by a multi blade tungsten carbide bur (D&Z, cc129fx) with a speed of 30,000 rpm only to refresh the composite resin and before reaching the metal mesh of the bracket base. The bracket base refreshing was undertaken with special care not to expose the metal mesh. The teeth were then rebonded with the prepared brackets as per previously described and according to the instructions of the company. The control group brackets were bonded according to the standard manufacturer guidelines. All the samples were then placed in the 37°C distilled water for 24 h before moving on to thermocycling machine to simulate oral environment. The thermocycling procedure was as follows: 500 thermo cycles of 5-55°C in distilled water each for 15.

Second debonding: On debonding, samples were attached to the Hunsfieldtest equipment machine H5KS, by means of a debonding plier (346 ETM, California , USA) gripping the brackets on mesial and distal surfaces (Fig. 1). All the samples in each of the 4 groups were applied a shear force with a cross head speed of 0.5 mm sec^{-1} to determine the rebond shear strength. In order to determine the rebond shear strength, the actual debonding force (per newton) should be calculated first. This is because the debonding forces recorded by the Instron machine are not equal to the actual debonding forces applied at the bracket adhesive interface. To this end, Bishara *et al.* (1994)'s formula was utilized (Fig. 2). The actual debonding forces (per N) were then divided by the bracket area unit (11.48 mm^2 as per manufacturer's instructions) to yield the bond strength per Mpa.

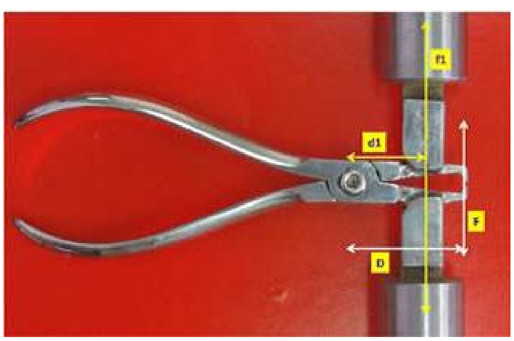

Fig. 2: Design of the vertically oriented force system. $F = f1 \times d1/D$ and $F = f1 \times 0.75$ where, F is actual debonding force, f1 is force applied by testing machine, D is the distance from pliers edge to hinge of the pliers (20 mm), d1 is the distance from midpoint of soldered metal bar to hinge of the pliers (15 mm)

Statistical analysis: In each group, the descriptive values including mean and standard deviation of shear bond strengths were calculated by mans of SPSS 17 Software. In order to compare the rebond strength of the brackets in each experimental group (A-C) with each other and also the control group (D), one-way Analysis of the Variance (ANOVA) with Tukey follow up test was used. The level of the significance was set at 0.05.

RESULTS AND DISCUSSION

Descriptive data: The values of mean and standard deviation of shear bond strength in each experimental group are described in Table 1. Two samples in the control group were lost and therefore a total of seventy eight samples were evaluated. Control group (group D) brackets had the highest mean bond strength while score IV^+ brackets (group A) had the second highest mean rebond strength. Score II^- brackets had the lowest mean rebond strength.

Analytical data: Comparison of the data by one way Analysis of the Variance (ANOVA) between the groups indicated that there was a significant difference between the groups (Table 2, $F = 15.2$, $p<0.05$).

Since, there were multiple groups in the study, a Tukey follow up test was utilized to locate the sources of the difference. As described in Table 3, score IV^+ brackets (group A, mean 13.9 MPa) had significantly higher rebond strength than the rebond strength observed in either of the brackets with ARI score of III (group C, mean 9 Mpa, $p<0.05$) or ARI score of II^- (group B, mean 8 Mpa, $p<0.05$). Furthermore, new brackets (control group, mean 15.6 MPa) had also a statistically significant higher bond strength than the aforementioned groups of B and C (group B, $p<0.05$; group C, $p<0.05$). However, the comparison between the bond strength of the new brackets (group D) with the rebond strength of the brackets in group A (ARI score IV^+) did not yield any statistically significant difference (Table 3, $p>0.05$).

Table 1: Distribution of bond strengths in the study groups

Sample groups	N	Minimum	Maximum	Mean	SD
Group A (score IV^+)	20	7.25	21.2	13.980	4.49
Group B (score II^-)	20	1.39	14.7	8.050	3.52
Group C (score III)	20	1.69	16.4	9.005	4.05
Group D (control group)	18	7.49	23.2	15.670	4.59

Table 2: ANOVA analysis for determining statistical difference between the groups

Bond strength	Sum of squares	df	Mean square	F-value	Sig.
Between groups	798.192	3	266.064	15.255	0
Within groups	1290.665	74	17.441	-	-
Total	2088.857	77	-	-	-

Table 3: Tukey follow up test for bilateral comparison of the mean values

Study groups	Mean difference	p-values
Control group		
ARI II$^-$	7.61 (*)	0
ARI III	6.67 (*)	0
ARI IV$^+$	1.69400	0.598
ARI II$^-$		
Control group	-7.61 (*)	0
ARI III	-0.94950	0.889
ARI IV$^+$	-5.9 (*)	0
ARI III		
Control group	-6.67 (*)	0
ARI II$^-$	0.94950	0.889
ARI IV$^+$	-4.97 (*)	0.002
ARI IV$^+$		
Control group	-1.6	0.598
ARI II$^-$	5.9 (*)	0
ARI III	4.976 (*)	0.002

*The mean difference is significant at the 0.05 level

Shear bond strength of new and rebonded/recycled brackets has been a subject of great interest in orthodontic research. Several techniques have been used for recycling of orthodontic brackets, i.e., removal of resin remnants and reuse of the debonded brackets. These methods include air abrasion (Tavares *et al*., 2006) silicon carbide grinding (Tavares *et al*., 2006), microetching (Eminkahyagil *et al*., 2006), direct flame (Yassaeim *et al*., 2013), laser treatment (Ishida *et al*., 2011; Yassaeim *et al*., 2013) and industrial processing (Tavares *et al*., 2006). The aim of recycling the debonded brackets is to reduce the cost of replacing new orthodontic accessories. Every successful recycling technique, should not only yield a reliable bond strength but also require a minimum level of armamentarium, be easy to use, consume minimum chair time and does not damage the bracket.

In a laboratory study by Yassaeim *at al*. (2013), four different techniques for rebonding were evaluated; Er:YAG laser, Sandblast, direct flame and Co2 laser. They found that Er:YAG laser and Sandblast had higher rebond strengths. Co2 laser which is the most frequently used laser in the orthodontic office, produced the least shear rebond strength value and fell under the clinically acceptable range. They recommended Er:YAG laser as the most efficient method but also noted that the mean values of shear rebond strength of flamed brackets, exceeded the minimum clinically adequate level and ranked above the Co2 laser. A drawback to laser reconditioning might therefore be that not all laser types could be suitable for this purpose and that the types that have been found useful are still expensive and may lack the economic cost-effectiveness. They stated that though burning the composite remnants yielded adequate bond strength, it caused discoloration of bracket which is undesirable for most patients and impose the risk of toxic inhalation of the by-products (Yassaeim *et al*., 2013). Furthermore, it is reported to negatively influence the physical properties of the bracket's metal alloy by reducing its hardness (Chetan and Muralidhar, 2011).

In a study by Tavares *et al*. (2006), comparing the aluminum oxide sandblasting with stone grinding and industrial recycling, researchers found that a protocol of 15-30 sec air abrasion with 90 μ particles from 10 mm distance yielded a higher rebond strength with no damage to the bracket bases (Tavares *et al*., 2006). On the other hand, a number of researchers have proposed that some Sandblasting Methods may actually serve to reduce the rebond strengths. Millett *et al*. (1993) and Arici *et al*. (2006), stated that adequate sandblast time increases the bond strength but prolonged sandblast time and larger aluminum oxide particles cause distortion of the bracket meshwork and subsequently end in decreased bond strength. From the aforementioned literature, it seems that sandblast technique may be to some extent a technique sensitive method but can be successfully done if appropriate procedure is followed.

In the study, researchers used a tungsten carbide bur to roughen the bracket base, taking care not to expose the metal mesh before rebonding. A similar study using four different methods including high speed tungsten carbide bur, Low speed tungsten carbide bur, Finishing disc and Microetcher found that except for microetcher technique, the rebond strengths were significantly higher than the control group (Eminkahyagil *et al*., 2006). They attributed the increased rebond strength to an increase in the enamel roughness after resin removal and an increase in the mechanical retention of the debonded brackets cleaned by either tungsten carbide bur or finishing disc. One difference of the study with this research was that in the aforementioned study, researchers did not consider the ARI score as a possible factor in the rebonding strength. A further difference was that in the aforementioned study, researchers removed the entire remaining adhesive before rebonding while in the study researchers only used a mild roughening of the residual resin.

The results showed that the bracket group which had the highest ARI score (IV$^+$) had a relatively comparable bond strength than that of the new brackets. Furthermore, when low ARI index brackets (II$^-$ and III) were compared with the score IV$^+$ brackets, a statistically significant difference in favor of score IV$^+$ brackets were observed. Not surprisingly, however was the significantly higher bond strength of the control brackets in comparison with the low ARI index brackets (score II$^-$ and III). These findings indicate that when the bracket failure is predominantly in the adhesive-enamel interface, i.e., most of the adhesive remains on the bracket base, these brackets may be a better candidate for rebonding purposes provided that no structural or physical damage has been sustained by the bracket. However, low ARI index brackets with failure primarily on the bracket-adhesive interface may not be suitable for the rebonding processes. This suggestion is despite the fact that the mean observed rebond strengths in all the groups, even the low ARI index brackets were indeed above the minimum recommended value for successful bond strengths. The reason for being tentative for low ARI index is that their rebond strength was only marginally over the recommended minimum value for successful bond specially when considering the differences of laboratory with oral environment.

One possible explanation to the fact that high ARI score brackets had a high rebond strength with a comparable value to new brackets may be that combined chemical and micromechanical bond between composite to composite might have been higher in the high ARI index brackets than low ARI brackets because of the higher sum of composite in the former type.

In a similar study, evaluating the bond strengths of rebonded brackets a mild grinding method was used (Egan *et al*., 1996). The initial bond was undertaken in two groups with different adhesives; group 1: no mix adhesive and group 2: paste-paste adhesive. The same brackets were rebonded after resin roughening with green stone taking care not to expose the metal mesh. They found that rebonding using a paste-paste adhesive system produced comparable bond strength with the initial bond. Furthermore, they concluded that rebonding may be a viable option when no damage to the debonded bracket has been made and the separation is primarily in the resin/enamel interface. This conclusion is similar to that of the study since researchers found that brackets with high ARI score (IV and above, i.e., brackets with separation at enamel/adhesive interface) had a higher mean rebond strength than that of low ARI index brackets (with separation at bracket/adhesive interface). A drawback to this technique is the side effects including possible changes to the effective in/out, torque and rotation preadjustments built into the brackets. The magnitude of these changes which are due to additional resin layer would have to be evaluated with respect to the magnitude of the natural variations in the facial structures of the teeth (Egan *et al*., 1996). Compensating bends if necessary can be made in the arch wire to fend off these side effects. At the end, as with any other laboratory study, caution should be taken in extrapolating the results to clinical level since the findings are laboratory findings. Factors related to clinical environment, e.g., different type of loading, different debonding method and different environment should be taken into account.

CONCLUSION

- Score IV and V brackets had a higher rebond strength than score I, II and III brackets
- Score IV and V brackets had a comparable rebond strength with new brackets
- As with any laboratory study, caution should be taken in extrapolating these findings to oral environment

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