 DOI: 10.18231/2455-6785.2017.0033

The changes in shear bond strength due to repeated bonding - an in vitro study

Manoj Kumar Sharma[1,*], Poonam Majumder[2], Heeralal Chokotiya[3], Mayank Sharma[4], Pratibha Sharma[5]

[1]Medical Officer, Health Dept. Govt. of Rajasthan, [2]Private Practitioner, Agra, Uttar Pradesh, [3,5]Senior Lecturer, Dept. of Orthodontics, [4]Senior Lecturer, Dept. of Pedodontics, Mansarovar Dental College, Bhopal, Madhya Pradesh

***Corresponding Author:**
Email: manu2smarty@gmail.com

Abstract

Orthodontist face a range of problems during treatment, one commonly being bracket failure. The reason for this occurrence is usually either because of the patient's inadvertently applying improper forces to the bracket or of a poor bonding technique. As a result of this a significant amount of precious clinical time is wasted in rebonding brackets in a busy orthodontic practice. This study evaluates the effect of repeated bonding on the shear bond strength of orthodontic brackets. Thirty freshly extracted human premolars were collected and stored in a solution of 0.1% (wt/vol) thymol. The teeth were cleaned, polished, and etched with a 37% phosphoric acid gel. The brackets were bonded with the adhesive and light cured for 40 seconds. The teeth were sequentially bonded and debonded 3 times with the same composite orthodontic adhesive. The results of the analysis of variance comparing the shear bond strength at the 3 debonding attempts indicated that, the highest values for shear bond strength were obtained after the initial bonding. Rebonded teeth have considerably lower and inconsistent shear bond strength. The shear bond strength after two debonding procedures significantly decreased, but was still above the recommended required bond strength.

Introduction

From the time when Buonocore introduced the acid etch bonding technique in 1955, the concept of bonding various resins to enamel has developed applications in all fields of dentistry,(1) including the bonding of orthodontic brackets.

By the late 1970s, bonding of orthodontic brackets became an accepted clinical technique.(2) Orthodontist face a range of problems during treatment, one commonly being bracket failure. The reason for this occurrence is usually either because of the patient's inadvertently applying improper forces to the bracket or of a poor bonding technique. As a result of this a significant amount of precious clinical time is wasted in rebonding brackets in a busy orthodontic practice. Before rebonding an orthodontic bracket, the following factors should be considered: reconditioning of the enamel surface, the use of new brackets or the original brackets and the bonding system to be used.

Some authors have stated that rebond strength is lower while others have stated that it is either comparable to or greater than that of original bond strength.(3) The differences can be attributed to differences among bonding systems and bracket types used or the method of reconditioning of enamel surface and bracket base.

The aim of this study was to assess the effect of repeated bonding on the shear bond strength of orthodontic adhesive keeping all the parameters same.

Materials and Method

Sample

- 30 freshly extracted human premolars.

Exclusion Criteria:

- The following exclusion criteria had been considered for selection of the samples-
  - i) Presence of cracks on enamel surface
  - ii) Carious tooth
  - iii) Teeth with restoration
  - iv) Tooth surface that has been previously treated with chemical agent
  - v) Presence of enamel hypoplasia

Storage

- Teeth collected were rinsed thoroughly under running tape water to remove any traces of blood or debris.
- Placed in 0.1% thymol solution to prevent dehydration and bacterial growth.

Bonding System

Adhesive: Transbond XT bonding system (3M Unitek) contains a liquid sealant and an adhesive paste. The latter is a composite that contains Bis GMA, Bis EMA, and quartz/silica fillers. The liquid sealant has essentially the same composition as the adhesive paste but without the fillers.

Etchant: d-tech [37% phosphoric acid gel].

Attachments: (Orthodontic Brackets)

Bonding of all teeth were done with stainless steel premolar brackets with hook (.022 MBT prescription, NU-EDGE, TP Orthodontics inc. Europe). New brackets were used for each bonding sequence.

Other materials used in the study include:

1. Self cure acrylic resin for making blocks.
2. Fluoride-free pumice powder for prophylaxis
3. Rectangular stainless steel wire (0.018 × 0.025 inch) for making wire loop

Equipment Used

1. Universal testing machine (Instron, Model No. 4444).
2. Curing light (L.E.D. system).
3. Stereo microscope (Leica MZ- 6).
4. Dental Surveyor.

Instrument Used

1. Dental explorer.
2. Bracket placement tweezer.
3. Applicator brushes.
4. Air-water syringe.
5. Bracket positioning gauge.
6. Hand piece.
7. Prophylactic rubber cups.
8. Finishing carbide bur(#279).

Preparation of specimen: Teeth were fixed in self-cure acrylic block (30X 25 X 15 mm) with the roots remaining completely embedded in acrylic block upto cemento- enamel junction. The acrylic blocks were numbered individually. Dental surveyor was used to orient each tooth, so that the buccal surface remains parallel to the applied force during shear bond strength test.

Prebonding Procedure: For all groups the buccal surfaces of the teeth were cleaned using a slurry of non-fluoridated pumice powder and water using rubber cup for 10 seconds followed by rinsing with water spray and drying with compressed air for 30 seconds.

Bonding Procedure

1. Teeth were etched with 37% phosphoric acid for 30sec.
2. Teeth were then washed with air water syringe for 15 sec.
3. This was followed by drying of teeth with compressed air for 5 sec. to get frosty white appearance
4. Transbond XT primer was then applied on the tooth surface and the surface had been allowed time to dry.
5. Transbond adhesive was applied to the under side of the bracket base and placed in firm contact with the tooth surface.
6. Adhesive was light cured for 40 sec.(10 sec from each side i.e. mesial, distal, occlusal, gingival)

Shear Bond Strength Test

Shear bond strength was measured on universal testing machine (INSTRON, Model No 4444). Instron machine consists of an upper clasp (movable head) and lower clasp (fixed head).

Debonding procedure was done using a wire loop, made of rectangular stainless steel wire (0.018 × 0.025inch**)**. The wire was fixed in an acrylic resin block which was mounted to the upper grip of the machine. The specimen mounted in its acrylic block was secured to lower grip of the machine. Buccal surface of the teeth with bracket was oriented parallel to the shearing force during testing. The force was applied to the bracket in a gingivo-occlusal direction at a cross-head speed of 5mm/min until bond failure occurred. Bracket removal was performed within a half hour from the time the teeth are bonded.

The breaking load was recorded in a computer electronically connected to the universal testing machine. The breaking load values recorded in Kilo Newton(KN) was converted to Newton . Thus force values obtained in Newton has to be divided by the bracket base area. That will convert the values into mega pascal unit.

Shear bond strength was calculated by using the following formula

$$\text{Shear Bond Strength (Mpa)} = \frac{\text{Breaking load (force in Newton)}}{\text{Bracket surface area in mm}^2}$$

The average bracket base surface area was reported by manufacturer to be 9.8 mm^2.

Repeated Rebonding: After each debonding, finishing carbide bur (#279; Brassler USA, Savannah, Ga) was used to remove the visible residual composite adhesive until the enamel surface regained its gloss. The teeth were then cleaned, and the bonding/ debonding procedures was repeated a total of three times on the same tooth surface with the same approach detailed earlier. During each series of bonding and debonding, the order of the teeth was maintained so that it is possible to compare the bond strength of each tooth in its proper sequence. This approach allowed for the evaluation of the changes that occur in the bond strength within each tooth on a longitudinal basis. All debonding were performed within a half hour from the time of bonding to simulate as much as possible the conditions that occur clinically, i.e., after a bracket fails and is replaced and tied to the arch wire.

After debonding of bracket, the debonded specimen was examined using a stereo microscope (Leica MZ- 6) under 10 x magnification and scoring will be done using modified adhesive remnant index (ARI).

The criteria for modified ARI score are as follows:-

Score 5=No adhesive remnant left on the tooth

Score 4=Less than 10% of the adhesive remnant on the tooth

Score 3=More than 10% but less than 90% of the adhesive remnant on the tooth.

Score 2=More than 90% of the adhesive remain on the tooth.

Score 1 = All of the composite remained on the tooth, along with the impression of the bracket base.

The site of the bond failure was recorded and scored after every debonding sequence, based on the Modified ARI Score.

Results

Shear bond strength of the total sample

- 12.4127±3.0804 MPa is the mean shear bond strength value displayed by samples after 1st debonding.

- 10.0287±2.3475 MPa is the mean shear bond strength value displayed by samples after 2nd debonding.
- 8.8617±2.6972 MPa is the mean shear bond strength value displayed by samples after 3rd debonding.

The descriptive statistics for the shear bond strength at the 3 bonding/debonding sequences are presented in Table 1. The results of the analysis of variance comparing the 3 experimental groups (F=13.24) indicated the presence of significant differences between the debonding group 1 and debonding group 2 ($P < 0.0013$) also between debonding group1 and debonding group 3($p < .0001$), but no significant difference found between debonding group 2 and debonding group 3($p < 0.0791$) presented in Table 2.

Table 1: Descriptive Statistics and the Results of the Analysis of Variance Comparing the Shear Bond Strengths (in MPa) of the 3 Bonding/Debonding Sequences on 30 Teeth

Analysis Variable: Debonding value						
Debonding	**No. of Obs**	**Mean**	**Std Dev**	**Std Error**	**Minimum**	**Maximum**
1	30	12.4126667	3.0803761	0.5623972	8.4900000	20.5700000
2	30	10.0286667	2.3475368	0.4285996	6.8100000	18.3600000
3	30	8.8616667	2.6972337	0.4924452	3.2100000	14.3800000

Table 2: The results of the analysis of variance comparing the 3 experimental groups indicated the presence and absence of significant differences between the debonding group 1, 2 and 3

Debonding	N	Mean	Std Dev	Std Err	Minimum	Maximum	95% CL Mean		Std Dev	95% CL Std Dev		DF	t Value	Pr > |t|
1 2	30	12.4127	3.0804	0.5624	8.49	20.57	11.2624	13.5629	3.0804	2.4532	4.141	58	3.37	0.0013
	30	10.0287	2.3475	0.4286	6.81	18.36	9.1521	10.9053	2.3475	1.8696	3.1558			
1 3	30	12.4127	3.0804	0.5624	8.49	20.57	11.2624	13.5629	3.0804	2.4532	4.141	58	4.75	<.0001
	30	8.8617	2.6972	0.4924	3.21	14.38	7.8545	9.8688	2.6972	2.1481	3.6259			
2 3	30	10.0287	2.3475	0.4286	6.81	18.36	9.1521	10.9053	2.3475	1.8696	3.1558	58	1.79	0.0791
	30	8.8617	2.6972	0.4924	3.21	14.38	7.8545	9.8688	2.6972	2.1481	3.6259			

Changes in bond strength between debonding sequences: On evaluation of the changes between the three debonding sequences, the findings (Table 3) indicated that between the first and second debonding sequence, 24 teeth had a significant decrease in shear bond strength (mean ± SD, -3.5 ± 2.7 MPa; $P < .0001$), where as 6 teeth had an increase (mean ± SD, 2.28 ± 1.6 MPa; $P = .019$). Between debonding sequences 2 and 3, 17 teeth had a significant decrease (mean ± SD, -2.8 ± 2.2 MPa; $P < .0001$), whereas 13 teeth had a significant increase (mean ± SD, 0.99 ± 0.8 MPa; $P = .001$) in shear bond strength. When the overall change in shear bond strength within each tooth was evaluated between debonding sequences 1 and 3, 26 teeth had a significant decrease (mean ± SD, -4.5 ± 4.0 MPa; $P < .0001$) in bond strength, whereas 4 teeth had an increase in shear bond strength that was not statistically significant (mean ± SD, 2.6 ± 1.8 MPa; $P = .06$).

Adhesive remnant index: The ARI scores for the 3 groups tested are presented in Table 4. The chi-square test results ($x^2 = 8.95$) indicate the absence of a significant difference among the 3 groups ($P = .346$). In general, the ARI scores did not shift significantly within each tooth among the various debonding sequences.

Table 3: Descriptive Statistics and Results of the Student's t-test Comparisons of the Changes in Shear Bond Strength between the 3 Bonding/Debonding Sequences

		N	Mean	Percentage	Std Dev	Std Err	Minimum	Maximum	95% CL Mean		Std Dev	95% CL Std Dev		DF	t Value	Pr > |t|
Debonding (1,2)	Decrease	24	-3.55	-27.2919	2.7947	0.5705	-11.17	-0.44	-4.7301	-2.3699	2.7947	2.1721	3.9203	23	-6.22	<.0001
	Increase	6	2.28	22.72425	1.6514	0.6742	0.23	4.78	0.547	4.013	1.6514	1.0308	4.0502	5	3.38	0.0196
Debonding (1,3)	Decrease	26	-4.5046	-35.2707	4.0128	0.787	-14.19	-0.92	-6.1254	-2.8838	4.0128	3.1471	5.5394	25	-5.72	<.0001
	Increase	4	2.6475	26.26488	1.8563	0.9282	0.65	5.08	-0.3063	5.6013	1.8563	1.0516	6.9214	3	2.85	0.065
Debonding (2,3)	Decrease	17	-2.8176	-27.6687	2.2531	0.5465	-9.27	-0.3	-3.9761	-1.6592	2.2531	1.678	3.429	16	-5.16	<.0001
	Increase	13	0.9915	10.09081	0.8564	0.2375	0.03	3.47	0.474	1.509	0.8564	0.6141	1.4136	12	4.17	0.0013

Table 4: Frequency Distribution of the Adhesive Residual Index (ARI) Scores and the Results of x^2 Comparisons of the 3 Bonding/Debonding Sequences Tested on 30 Teeth

Table of Debonding by Bonding/Debnding sequence							
		Bonding/Debnding sequence					**Total**
		1	**2**	**3**	**4**	**5**	
Debonding		2	10	18	0	0	30
1	Frequency						
	Row Pct	6.67	33.33	60.00	0.00	0.00	
2	Frequency	0	12	15	2	1	30
	Row Pct	0.00	40.00	50.00	6.67	3.33	
3	Frequency	1	13	14	0	2	30
	Row Pct	3.33	43.33	46.67	0.00	6.67	
Total	Frequency	3	35	47	2	3	90

Discussion

The results of the present study show a noteworthy decline in the shear bond strength after each debonding sequence. The highest shear bond strength (mean = 12.41 MPa) was observed in the first debonding sequence, followed by the second and third stages (Mean 10.02 and 8.86 MPa, respectively).

In present study significant decrease in shear bond strength found in debonding group 1 and 2($p < .0013$), also between debonding group 1 and 3($p < .0001$), but no significant difference found between debonding group 2 and debonding group 3($p < 0.0791$).

The observations of the present study show that highest shear bond strength was found in the first debonding sequence, followed by a decline in the second and third debonding sequences. These findings correlate with the findings of the study by Bishara et al[(4)] and Ladan Eslamian[5] in which they found significant decline in shear bond strength seen after subsequent debonding sequences. The present study findings are more similar to the study by Bishara et al[(4)] in which there is significant decrease in shear bond strength found between first and second debonding, also between first and third debonding but between second and third debonding shear bond strength decrease is non significant.

Modified Adhesive Remnant Index (ARI) which was used in the study by Bishara et al[(3,5)] has been used in the present study, which helps to better define the site of bond failure among the enamel, the adhesive, and the bracket base. An analysis of the failure sites demonstrated that ARI scores were found to be similar after all three debonding sequences i.e. there is no statistical significant difference found in ARI score after three debonding sequences. However, the similar pattern of ARI did not explain the changes in shear bond strength, which needs further investigation using the scanning electron microscopic (SEM) technique. The ARI results of the present study are similar to that in studies by Bishara et al[(4)] and Eslamian L.[(5)]

The observed reduction in the shear bond strength is most likely due to the fractional destruction of the etching pattern as shown by Ruger[(6)] and Fischer Brandics[(7)] in their studies. The weaker retentive enamel morphology could be due to retention of composite residue after first debonding seen in study by Bishara et al and Regan.[(8)]

The average shear bond strength after two debonding processes was still above the recommended 5.9-7.8 MPa which is given by Reynolds[(9)] in his study.

The limitations of the *in-vitro* studies should be considered in interpreting the present findings. Most reported *in-vivo* bond strengths might not be as high as those measured using the *in-vitro* models. The average reported *in-vivo* bond strengths were approximately 40% less than the *in-vitro* studies.[(10)] The gradual decrease in bond strength of composites due to aging and storage of material in saliva is another factor that should be considered before making clinical recommendations.[(11)]

After taking into consideration the various limitations that have been discussed above, the findings of the present study suggest that the average shear bond strength of new stainless steel brackets reduced after two debonding procedures, but is still above the recommended required bond strength.

Conclusion

The following conclusions can be drawn from the present study:

1. In general, the highest values for shear bond strength were obtained after the initial bonding.
2. Significant decrease in shear bond strength was seen between debonding sequence 1 and debonding sequence 2.
3. Significant decrease in shear bond strength was seen between debonding sequence 1 and debonding sequence 3.
4. Non significant decrease in shear bond strength was seen between debonding sequence 2 and debonding sequence 3.
5. In between debonding sequence 1 and 2, large number of samples show statistically significant decrease in shear bond strength (24 of 30) and few

samples shows increase in shear bond strength(6 of 30).

6. In between debonding sequence 1 and 3, large number of samples show statistically significant decrease in shear bond strength (26 of 30) and few samples shows increase in shear bond strength(4 of 30) that is not statistically significant.
7. In between debonding sequence 2 and 3 almost nearly equal number of samples show statistically significant decrease and increase in shear bond strength.
8. No statistical significant difference found in modified Adhesive Remnant Index (ARI) score after three debonding sequences.
9. Rebonded teeth have considerably lower and inconsistent shear bond strength. This observation indicates that bond strength may further decrease or increase after the second debonding. The changes in bond strength could probably be related to the changes in the morphologic characteristics of the etched enamel surface as a result of the presence of adhesive remnants.
10. The shear bond strength of new stainless steel brackets after two debonding procedures significantly decreased, but was still above the recommended required bond strength (5.9-7.8 MPa).

References

1. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J Dent Res.* 1955;34: 849–853.
2. Newman GV. Epoxy adhesives for orthodontic attachments. Am J Orthod.1965;51:901-912.
3. Mui B, Rossouw PE, Kulkarni GV. Opitimization of a procedure for rebonding dislodged orthodontic brackets. *Angle Orthod.* 1999;69:276–281.
4. Samir E. Bishara, John F. Laffoon, Leigh VonWald, DDS, and John J. Warren. The effect of repeated bonding on the shear bond strength of different orthodontic adhesives .Am J Orthod Dentofacial Orthop 2002;121:521-5.
5. Ladan Eslamian, Ali Borzabadi-Farahani, Pegah Tavakol, Ali Tavakol, Nazila Amini, and Edward Lynch. Effect of multiple debonding sequences on shear bond strength of new stainless steel brackets. J Orthod Sci. 2015 Apr-Jun;4(2):37–41.
6. Rüger D, Harzer W, Krisjane Z, Tausche E. Shear bond strength after multiple bracket bonding with or without repeated etching. Eur J Orthod. 2011;33:521–7.
7. Fischer-Brandies H, Monsees M. Enamel damage from multiple debonding in the bracket adhesion technic. Fortschr Kieferorthop. 1993;54:143–7.
8. Regan D, LeMasney B, van Noort R. The tensile bond strength of new and rebonded stainless steel orthodontic brackets. Eur J Orthod. 1993;15:125–35.
9. Reynolds IR. A review of direct orthodontic bonding. Br J Orthod. 1975;2:171–8.
10. Manar K.A. Hajrassie and Salwa E. Khier. In-vivo and in-vitro comparison of bond strengths of orthodontic brackets bonded to enamel and debonded at various times. Am J Orthod Dentofacial Orthop 2007;131:384-90.
11. Hariri I, Shimada Y, Sadr A, Ichinose S, Tagami J. The effects of aging on shear bond strength and nanoleakage expression of an etch-and-rinse adhesive on human enamel and dentin. J Adhes Dent.2012;14:235–43.