

Immediate versus Delayed Force Application after Orthodontic Bonding; An In Vitro Study

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Abstract:

Statement of Problem: Bracket de-bonding during initial orthodontic archwire placement immediately after bracket set up or following re-bonding a single bracket can be a clinical concern.

Purpose: The aim of this in vitro study was to assess the effect of time on the shear bond strength of a no-mix orthodontic composite adhesive.

Materials and Methods: Seventy freshly extracted human upper first premolars were collected and stored in normal saline solution. The teeth were cleaned, polished, and randomly separated into 7 groups of 10. First premolar mesh-backed standard edgewise brackets were bonded to all specimens using a no-mix orthodontic composite adhesive. In the first 6 groups, the brackets were de-bonded 2, 5, 10, 15, 30 and 60 minutes after the primary setting time and the shear bond strengths were determined with the Universal testing machine. The teeth in group 7 were stored in 100% humidity at 37°C for 24 hours before de-bonding. Data were statistically analyzed with one-way ANOVA and the Duncan multiple range analyses via SPSS software.

Results: The minimum shear bond strength of 14.03 MPa was observed in group 1. A statistically significant difference was found between the shear bond strength of group 1 and the other groups ($P < 0.05$). The shear bond strength increased significantly with time up to the first 5 minutes after bonding, but did not change afterwards.

Conclusion: The bracket and composite adhesive used in this study demonstrated initial bond strengths of sufficient magnitude to withstand the immediate application of orthodontic forces, even 2 minutes after the primary setting time. Therefore, the operator should not be concerned with bracket de-bonding due to primary arch wire placement during the first minutes after bracket set up or following re-bonding a single bracket.

Key Words: Shear bond strength; Universal testing machine; No-mix composite; In-vitro study

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INTRODUCTION

The acid etch bonding technique was first introduced in 1955 by Buonocore [1]. From then on the concept of bonding various resins to enamel has developed applications in all fields of dentistry including bonding of orthodontic brackets. According to the literature the rate of bracket failure varies from

1 to 7.2 percent [2-5]. Bracket failure may develop for different reasons and in different stages of treatment. Reynolds reported that the necessary bond strength (BS) for orthodontic brackets to withstand de-bonding in normal conditions is between 5.9 to 8.7 MPa [6]. The BS of different bonding materials, the effect of etch time the role of debonding devices in

assessing BS, and the effect of thermocycling and tooth type on BS, have been previously demonstrated [7-17]. The aim of this in vitro study was to assess the effect of time on the shear bond strength of a no-mix orthodontic composite adhesive, i.e. Dentaurum, to determine whether the initial bond strengths are of sufficient magnitude to withstand the immediate application of orthodontic forces after bracket set up or following rebonding a de-bonded bracket

MATERIALS AND METHODS

This investigation was an in vitro experimental study. The sample consisted of seventy human upper first premolars extracted for orthodontic purposes. The criteria for tooth selection included intact buccal enamel that had not been subjected to any pretreatment chemical agents, eg, hydrogen peroxide, with no cracks due to the pressure of extraction forceps, and no caries. All teeth were cleaned, washed, and stored in normal saline solution after extraction, prior to being used.

A piece of $.017 \times .025$ inch stainless steel wire was spot welded to a standard $.018$ -inch stainless steel edgewise premolar mesh-backed bracket (Dentaurum, Germany) along its vertical axis. One end of the wire was bent at a 90 degrees angle approximately 6 mm from the center of the bracket to make a handle for fixation on a metallic jig with the inner diameter of 25 mm. A thin line was scratched 4 mm from the center of the bracket on the opposite end of the wire, as a guide-line for mounting the teeth in their exact locations, parallel to the tip of the cusp. A New-Pipe tube was placed inside the jig and was filled with a cold cured acrylic (Acropars, Iran). The prepared wire was firmly fixed on the metallic jig with stick paper while carrying the bracket with its lingual surface facing the center of the jig (Fig. 1). Each tooth was inserted into the acrylic. At this point the scratched guide-line was parallel to the tip of the cusp. After the

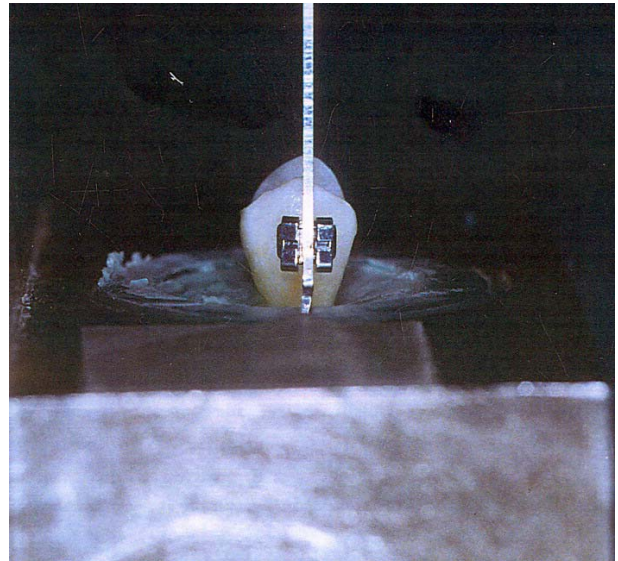


Fig.1: Mounting the index bracket on premolar teeth

acrylic was set, the New-Pipe tube, now carrying the mounted tooth, was placed in normal saline solution. The enamel surface of each tooth was pumiced using a rubber cup in a contra-angle handpiece before being etched for 60 seconds with 37 percent phosphoric acid according to the manufacturer's instructions. The teeth were subsequently washed with 5cc distilled water, and air-dried with oil-free compressed air for 15 seconds. The etched area of the tooth and the base of the bracket were painted with a thin layer of primer. A no-mix chemical cured adhesive (Dentaurum, Germany) was then placed on the base of the bracket, and the bracket was positioned using a 4-mm gauge. According to the information provided by the manufacturer, the setting time of the composite adhesive used in this study was 60 seconds therefore, the New-Pipe tube carrying each bonded specimen was set aside for 60 seconds and was secured in a metallic jig.

Experimental de-bonding of brackets was carried out at intervals of 2, 5, 10, 15, 30, and 60 minutes in the first 6 groups; and 24 hours in the 7th group, during which the teeth were kept in an incubator at 100% humidity and 37°C temperature. An Instron Universal testing



Fig.: Setup of the experiment; path of force application

machine (Instron Corp, model 8500, Canton, MA, USA) with a cylindrical cross-head diameter of 1.5 mm set at a speed of 5 mm/min, positioned perpendicular to the bracket (Fig 2) was used for the debonding procedure.

The average surface area of the bracket base was determined to be 9.8 mm², using the shadowgraph technique [7]. The shear bond strength (MPa) at failure was measured for each specimen.

The Kolmogorov-Smirnov test, one-way ANOVA and Duncan multiple range analyses were used for statistical analysis via SPSS software.

RESULTS

According to the Kolmogorov-Smirnov ($\alpha=0.05$) test, the data distribution was normal.

The mean shear bond strength, standard deviation and standard error of each group are shown in Table I. The lowest and highest amounts of mean shear bond strength were 14.3 and 21.61 MPa, and encountered in the 1st and 7th groups respectively.

One-way ANOVA showed a statistically significant difference between the mean shear bond strengths of the study groups ($P<0.05$).

The Duncan multiple range test (Table II) revealed a significant difference between group 1 and the other groups ($P<0.05$).

The shear bond strength increased significantly only in the 1st and 2nd groups, 5 minutes after bonding. The remaining groups did not show a significant increase (Fig. 3).

DISCUSSION

Shear bond strength of orthodontic composite adhesives depends on many variables such as: etch time, type of tooth, time of force application following bonding, the substrate used for storing the teeth, the temperature of the environment, the speed of mixing the two parts of the composite adhesive or the amount of each part, and the practitioner [9-12].

Table I: Descriptive statistics of mean shear bond strengths (in MPa), standard deviation (SD), minimum, and maximum for tested groups.

Group	N	Mean	S.D.	95%		Min.	Max.
				L.B	U.B		
2min	10	14.0310	2.03527	12.5751	15.4869	11.22	17.31
5min	10	19.5970	1.92817	18.2177	20.9763	14.97	21.52
10min	10	20.6740	1.89430	19.3189	22.0291	17.31	23.39
15min	10	21.1450	2.62741	19.2655	23.0245	16.38	24.80
30min	10	19.2720	2.54987	17.4479	21.0961	15.43	23.39
60min	10	20.5830	1.63075	19.4164	21.7496	17.33	22.45
24h	10	21.6190	3.00159	19.4718	23.7662	16.38	27.13
Total	70	19.5601	3.24791	17.9550	20.3334	11.22	27.13

orthodontic composite adhesive, measured in vitro, increased significantly ($p < 0.05$) up to 5 minutes after the primary setting time. A slight but insignificant increase was also observed, up to 24 hours after bonding. A significant difference was encountered between the shear bond strength of the first group and the other groups but the difference was not significant in the remaining 6 groups. Reynolds [6] suggested that minimum bond strength of 5.9 to 7.8 MPa was adequate for most clinical orthodontic needs. The first group in the present study had the lowest shear bond strength (14.03 MPa), which was still below these optimal limits. Although the test conditions were similar in all groups, an insignificant decrease occurred in group 5 (the 30-minute group). The reason for this reduction is unclear but it may be related to the quality and the setting process of the tested material.

Bishara et al [8] studied the effect of time on the shear bond strength of Fuji Ortho LC resin-modified glass ionomer and Transbond XT light-cure composite adhesives. Maxillary central incisor brackets were bonded to the buccal surfaces of freshly extracted human first molars. Their findings showed that the resin reinforced glass ionomer adhesive had significantly lower initial bond strength that increased more than 20-fold within 24 hours.

Table II: Results of Duncan multiple range test.

Group	N	Subset for alpha = 0.05		
		1	2	3
2min	10	14.0310		
30min	10		19.2720	
5min	10		19.5970	19.5970
60min	10		20.5830	20.5830
10min	10		20.6740	20.6740
15min	10		21.1450	21.1450
24h	10			21.6190
P-value		1.000	0.107	0.081

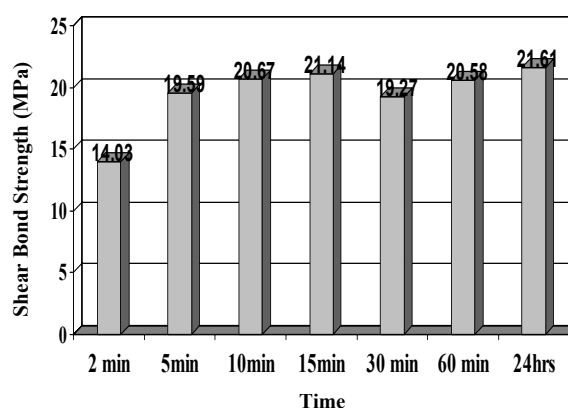


Fig. 3: The results of shear bond strength in different time intervals.

In comparison, the composite adhesive had a significantly larger initial bond strength that doubled within 24 hours. These findings differ from the results obtained in the present investigation, which may be explained by the different materials and teeth used in the two studies.

In a similar report, Bishara et al [9] compared the effect of time on the shear bond strength of Smart Bond cyanoacrylate and Transbond XT light cure composite adhesives. They found that with both materials the bond strength increased with time and that the bond strength was greater in the composite adhesive than the cyanoacrylate adhesive. Their findings indicated that the tested cyanoacrylate and composite adhesives had clinically adequate shear bond strengths at half an hour and 24 hours after initial bonding. According to the current investigation, the shear bond strength of the tested no-mix composite adhesive increased only in the first 5 minutes after bonding but there was no significant increase in bond strength afterwards until 24 hours post-bonding. Even 2 minutes after bonding, the shear bond strength was adequate for placing the initial arch wires.

Chamda et al [10] compared the time-related bond strength of a light-cured (Transbond XT) and a chemically-cured (Concise) bonding system. They found the bond strength of the

chemically cured system to be initially low (up to 5 minutes after bonding), and of insufficient magnitude to withstand the immediate application of orthodontic forces. Their light-cured sample displayed initial bond strengths of sufficient magnitude to withstand the immediate application of orthodontic forces which increased with time. They did not find a significant difference between the bond strengths achieved by the chemically cured and light-cured systems at the 10-minute, 60-minute, and 24-hour intervals. This is in contrast to the results obtained in the present investigation; the bond strength of the studied chemically-cured composite adhesive (Dentaram) was of sufficient magnitude to withstand the immediate application of orthodontic forces, 2 minutes after bonding.

Bin Abdullah [11] studied the effect of etch time and debond intervals on the shear bond strength of metallic orthodontic brackets bonded to maxillary first premolars with no-mix Right On composite adhesive. They stated that an etch time of 30 seconds with 37% phosphoric acid would be necessary if the bracket was to be ligated within 5 minutes after bonding, but if it has been decided to apply the force 15 minutes after bonding, 15 seconds of etch time would be sufficient. Oslen et al [12] in another study recommend 20 to 30 seconds of etch time. In our study the teeth were etched for 60 seconds according to the manufacturer's instructions.

Pickett et al [13] and Pecora et al [14] showed that the type of debonding device and cross-head also affect the results of bond strength analysis. Consequently an Instron Universal testing machine with a cylindrical cross-head has been recommended. An Instron Universal testing machine with a cylindrical cross-head (diameter=1.5 mm) set at a speed of 5 mm per minute was used in the present study.

It is noteworthy that in vivo situations may be quite different from laboratory environments. Bishara et al [15] showed that thermocycling

at 5°C and 55°C decreased the shear bond strength up to 80 percent as compared to brackets immersed in deionized water at 37°C for 24 hours. It seems that the instability of the oral environment may affect the shear bond strength of orthodontic adhesives. According to Murray et al [16], brackets debonded after 4 weeks in vivo had significantly lower bond strengths (9.78 MPa) than did the controls (14.34 MPa) which were stored in sterile water at 37°C. Pickett et al [13] also showed that mean bond strengths recorded in vivo following comprehensive orthodontic treatment are significantly lower than bond strengths recorded in vitro. In vivo, the bonding systems are exposed to numerous intraoral factors including saliva, acid, masticatory forces, variable patient abuse, and orthodontic mechanotherapy during the time period of comprehensive orthodontic treatment [13]. Therefore, it seems that postponing bracket ligation assuming that the bond strength of brackets will increase, as occurs in vitro, may not be a wise and logical decision.

Tooth type was found to have a significant effect on bond strength [17]. Hobson et al [17] demonstrated that the minimum and maximum bond strength belongs to maxillary and mandibular molars, respectively. In the upper arch, bond strength was reported to be greater on anterior teeth than posterior teeth. The bond strength of maxillary first premolars, selected for the present study, falls somewhere in between. Therefore, regarding the results of the current study and findings by Reynolds [6], it can be concluded that 2 or at most 5 minutes after bonding, the initial bond strengths are of sufficient magnitude to withstand immediate application of orthodontic forces.

CONCLUSION

1- The minimum shear bond strength (14.03 MPa) was encountered 2 minutes after the primary setting time of the composite adhesive.

2- A significant difference was observed between the shear bond strengths of the 2-minute group and the other groups ($P < .05$).

3- The minimum shear bond strength of all groups was greater than the minimum shear bond strength necessary to withstand initial orthodontic forces.

4- The bracket and composite adhesive used in this study demonstrated initial bond strengths of sufficient magnitude to withstand the immediate application of orthodontic forces, i.e. 5.9-7.8 MPa, shortly (even 2 minutes) after the primary setting time. Therefore, the operator should not be concerned with bracket de-bonding due to primary arch wire placement during the first minutes after bracket set up or following rebonding a single bracket.

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REFERENCES

1- Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surface. *J Dent Res* 1955;34:849-53.

2- Zachrisson BU, Büyükyilmaz T. Bonding in orthodontics. In: Graber TM, Vanarsdall RL, Vig KW, editors. *Orthodontics: Current principles and techniques*. 4th ed. St Louis: Mosby; 2005. p. 557-645.

3- Linklater RA, Gordon PH. Bond failure patterns in vivo. *Am J Orthod Dentofacial Orthop* 2003; 123: 534-9.

4- Ireland AJ, Sherriff M. The effect of timing of archwire placement on in vivo bond failure. *Br J Orthod* 1997; 24: 243-45.

5- Adolfsson U, Larsson E, Ogaard B. Bond failure of a no-mix adhesive during orthodontic

treatment. *Am J Orthod Dentofacial Orthop* 2002; 122: 277-81.

6- Reynolds IR. A review of direct orthodontic bonding. *Br J Orthod* 1979; 2: 171-8.

7- Beer P. *Mechanics of materials*. 3rd ed. Boston: McGraw Hill; 1990.

8- Bishara SE, VonWald L, Olsen ME, Laffoon JF. Effect of time on the shear bond strength of glass ionomer and composite orthodontic adhesives. *Am J Orthod Dentofacial Orthop* 1999; 116: 616-20.

9- Bishara SE, Laffoon JF, VonWald L, Warren J. Effect of time on the shear bond strength of cyanoacrylate and composite orthodontic adhesives. *Am J Orthod Dentofacial Orthop* 2002; 121: 297-300.

10- Chamda RA, Stein E. Time-related bond strength of light-cured and chemically cured bonding systems: An in vitro study. *Am J Orthod Dentofacial Orthop* 1996; 110: 378-82.

11- Bin Abdullah M, Rock WP. The effect of etch time and debond interval upon the shear bond strength of metallic orthodontic brackets. *Br J Orthod* 1996; 23: 121-4.

12- Olsen ME, Bishara SE, Boyer DB, Jakobsen JR.. Effect of varying etching times on the bond strength of ceramic Brackets. *Am J Orthod Dentofacial Orthop* 1996; 109: 403-9.

13- Pickett KL, Sadowsky PL, Jacobson A, Lacefield W. Orthodontic in vivo bond strength: Comparison with in vitro results. *Angle Orthod* 2001; 71: 141-8.

14- Pecora N, Yaman P, Dennison J, Herrero A. Comparison of shear bond strength relative to two testing devices. *J Prosthet Dent* 2002; 88: 511-5.

15- Bishara SE, Ajlouni R, Laffoon JF. Effect of thermocycling on the shear bond strength of a cyanoacrylate orthodontic adhesive. *Am J Orthod Dentofacial Orthop* 2003; 123: 21-4.

16- Murray SD, Hobson RS. Comparison of in vivo and in vitro shear bond strength. *Am J Orthod Dentofacial Orthop* 2003; 123: 2-9.

17- Hobson RS, McCabe JF, Hogg SD. Bond strength to surface enamel for different tooth types. *Dent Mater* 2001; 17: 184-9.