

Rebonding of unused brackets with different orthodontic adhesives

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Objective: To compare *in vitro* shear bond strength (SBS) of different orthodontic adhesives in bonding and repeatedly rebonding metal brackets, and to evaluate the bond failure site with the adhesive remnant index (ARI).

Methods: Specimens consisted of 90 extracted human first premolars, randomly divided into three groups (n=30). The adhesives Alpha Plast (AP), Concise™ (CO) and Transbond™ XT (TB) were used in each group. Three SBS tests were performed, i.e., one at T₀ (initial) and the other two at T₁ and T₂ (first and second rebondings, respectively), observing a 24-hour interval. The tests were performed in a Shimadzu AG-I (10kN) SBS testing machine, at a speed of 0.5 mm/min.

Results: SBS data were subjected to ANOVA, Tukey's test and Bonferroni test (p<0.05). For the ARI, the Kruskal Wallis test was performed, followed by the Dunn test. The results revealed that at T₀ groups AP and CO showed SBS values that were near, but above TB values; and at T₁ and T₂, the highest SBS values were observed for the AP group, followed by the CO and TB groups.

Conclusion: Statistically significant differences were found in SBS between groups AP, CO and TB during bonding and repeated rebondings of unused metal brackets, with group AP achieving the highest SBS value. Regarding ARI, adhesive AP exhibited bond failure at the enamel-adhesive interface, with a higher enamel fracture frequency.

Keywords: Shear bond strength. Brackets. Orthodontic adhesives. Rebonding.

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INTRODUCTION

Orthodontics has made significant improvements in recent decades with the use of new technologies that streamline orthodontic practice. The introduction of enamel acid etching¹ fostered the development of the direct bonding technique, which is currently the method of choice for placement of orthodontic accessories.²

Despite significant advances in orthodontic adhesives in recent years, studies regarding bonding show that 5 to 10% of clinical bond failures occur in both self-curing and light-curing composite resins.^{2,3,4} Bracket bond and rebonding failures are now commonplace, which can result in treatment delays and increased cost of orthodontic treatment maintenance.⁴ Bond failures may occur due to chewing, bonding procedure deficiencies or little retention of some bracket bases. It occurs most frequently in mandibular second premolars.⁵

When bracket bond failure occurs, it can be handled in three different manners: 1) Rebonding the reconditioned bracket, 2) Bonding of an unused bracket, and 3) Using a bracket welded to an orthodontic band in cases of persistent bond failures. Studies show that rebonding an unused bracket provides greater SBS than rebonding a recycled bracket.^{6,7,8}

Another aspect that has been addressed in different studies is the recycling of brackets, consisting of removal of the remaining adhesive from their base and reusing them. Bracket reuse, however, has been questioned in terms of biosafety and, from a mechanical standpoint, due to distortion of the bracket slot or base upon removal, which may result in (a) increased friction with orthodontic archwire, or (b) reduced adhesion, respectively. Furthermore, when rebonding brackets, unused or recycled, additional enamel loss may occur during debonding, on removal of adhesive remnant from the tooth surface, or during rebonding procedures.^{5,7}

In assessing the rebonding of unused brackets, Bishara et al⁸ highlighted the effect of repeated rebonding on SBS in a sample of 15 extracted human molars using metal upper central incisor brackets (Victory Series™ - 3M). The brackets were bonded and rebonded with Transbond™ XT adhesive system (3M Unitek) three times using unused brackets. Bracket bonding involved 300 g of pressure prior to light-curing. Shearing test was performed with a Zwick mechanical testing

machine at 5 mm/min speed. In all trials, the brackets were debonded 30 minutes after bonding. ANOVA results for the three debonding times showed no significant difference between groups ($p=0.104$). However, when the total shearing load for each tooth was assessed between debonding sequences 1 and 3, ten teeth exhibited a significant SBS decrease ($p=0.001$) (4.6 ± 2.5 MPa), and five teeth showed significant increases (2.8 ± 1.6 MPa). These findings revealed that SBS may increase or decrease after second rebonding. Changes in SBS values may be related to changes observed in the morphological characteristics of each etched enamel surface due to adhesive remnant. The adhesive remnant index (ARI) showed no significant difference between the three groups.

Later, in 2002, Bishara et al⁹ evaluated the effect of bracket rebonding on the SBS of metal orthodontic brackets bonded and rebonded with two adhesive systems. Thirty-one freshly extracted human molars were used. Unused Victory Series™ maxillary central incisor brackets (3M) were employed in each bonding sequence. Group 1 ($n=15$) was bonded with Transbond™ XT (3M) and Group 2 ($n=16$) with SmartBond (Gestenco). A Zwick mechanical testing machine was used at a speed of 5 mm/min. Results showed statistically significant differences. Transbond™ XT (4.4 ± 2.3 MPa) showed a higher SBS than SmartBond™ (2.2 ± 2.6 MPa) in all tests. Overall, the teeth where brackets were rebonded had significantly lower SBS owing to the adhesive remnant on the enamel surface. The authors confirmed that changes in SBS may be related to changes in morphological characteristics of the enamel surface as a result of the presence of adhesive remnant.

The recent economic globalization has significantly reduced the costs of orthodontic accessories, leading orthodontists to rebond unused brackets instead of recycled brackets. Bonding a new bracket seems to be faster and less risky than reconditioning used brackets to bond them anew. The aim of this study, therefore, was to compare the *in vitro* shear bond strength (SBS), using human premolars, of different orthodontic adhesives in bonding and repeatedly rebonding unused metal brackets, thereby evaluating and comparing bond failure sites, for each of the tested adhesives, using the adhesive remnant index (ARI).

MATERIAL AND METHODS

The research design was submitted to and approved by the Ethics Committee of the Ponta Grossa State University (COEP/UEPG) – Report #40/2006, Protocol 06269/06.

This study used 90 extracted maxillary premolars – all extractions indicated for orthodontic purposes – of patients aged between 12 and 14 years old. With the aid of a stereomicroscope magnifier (8x), the teeth were selected based on the following criteria: Intact buccal surface, cracks free, caries, restorations or fractures and not having received any kind of pretreatment with chemical agents. Careful cleaning, storage and selection of teeth were meant to avoid changes that might jeopardize adhesion.

Morelli metal brackets specific for canines and premolars were used. The brackets had a base area of 13.02 mm², and a 13.88 mm perimeter. These values were obtained automatically using the SolidWorks Software according to manufacturer instructions.

Ninety specimens were randomly divided into 3 groups (n=30), according to which composite resin was used: Group AP – Alpha Plast Orthodontic Adhesive (DFL), Group CO – Concise™ Orthodontic Adhesive (3M/ESPE), and Group TB – Transbond™ XT (3M Unitek). A prototype device especially developed by the authors for the placement of accessories was used to position all brackets. A 3M Unitek universal positioner and a Morelli dynamometer were modified. With this modification a device was obtained (Fig1) that positions the bracket and applies pressure evenly (300 grams), according to the method created by Bishara et al.^{8,9} Therefore, all brackets were bonded at a standard height of 4 mm and with a composite layer of uniform thickness. Before curing the material, all adhesive excess was removed with the aid of an explorer. All bonding procedures were performed by the same operator. After bonding, each specimen was stored for 24 hours in distilled water at room temperature in plastic containers with lids, separated and identified with specific numbering on the base of the PVC pipe according to each group, which were then subjected to mechanical shear tests. These tests followed the ISO/TR 11405 standard (2003) and were performed in a Shimadzu AG-I (10kN) testing machine at loading speed of 0.5 mm/min, and

the breaking loads were recorded in Newtons and converted to megapascal. Three SBS tests were performed for each of the experimental groups at three different times, i.e., T₀ (first bonding), T₁ and T₂, referring to the first and second rebonding, respectively. The interval between rebondings was 24 hours.

The adhesive remnant index (ARI) was observed with a stereomicroscope magnifier (Carl Zeiss, Brazil) with 8X magnification. The amount of adhesive remaining on the enamel after debonding was qualitatively assessed according to the scores used by Artun and Bergland.¹⁰ After recording the ARI at T₀, the adhesive remnants were removed with a special carbide bur manufactured by TP Orthodontics, using high speed and water cooling. After every 10 specimens, a new bur was used to ensure consistent cutting. After recording the ARI at T₁ and T₂, the adhesive remnant removal procedure was repeated and observing a polished enamel surface prior to rebonding, thus completing the experiment. This methodology is simplified in Figure 2.

RESULTS

Table 1 presents the SBS values in MPa, with means and standard deviations for each experimental group under study.

The quantitative variable “shear bond strength” was evaluated taking into account the variation factor “experimental group”, in a total of three groups: AP group, CO group and TB group, and time variation factor at 3 times (T₀ – bonding, T₁ – first rebonding and T₂ – second rebonding). According to the null hypothesis (H₀) the three materials tested at the 3 times should promote identical shear bond strength. Normal data distribution was confirmed

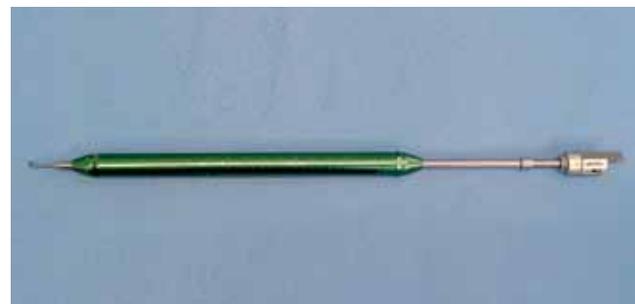


Figure 1 - Prototype of positioner modified by the authors.

Sample	T ₀	T ₁ (after 24 hours)	T ₂ (after 48 hours)
Alpha Plast (n=30)	Initial bonding + shearing + ARI	First rebonding + shearing + ARI	Second rebonding + shearing + ARI
Concise (n=30)	Initial bonding + shearing + ARI	First rebonding + shearing + ARI	Second rebonding + shearing + ARI
Transbond XT (n=30)	Initial bonding + shearing + ARI	First rebonding + shearing + ARI	Second rebonding + shearing + ARI

Figure 2 - Methodology applied to each group.

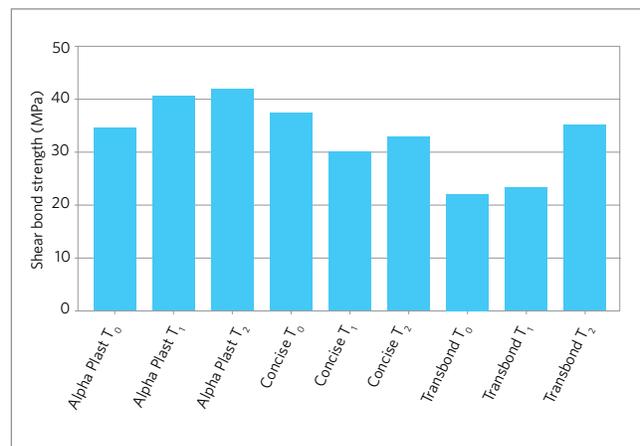


Figure 3 - Mean shear bond strength for each experimental group.

Table 1 - SBS values in MPa, means and standard deviations for each experimental group under study at T₀, T₁ and T₂

Adhesive	1 st Test - T ₀			2 nd Test - T ₁			3 rd Test - T ₂		
	AP	CO	TB	AP	CO	TB	AP	CO	TB
Mean	34.18	36.74	22.83	40.28	29.43	23.20	40.71	32.48	25.85
s.d.	13.50	11.25	7.10	11.21	6.54	7.19	8.74	7.79	19.17

by the Kolmogorov Smirnov test, which allowed the parametric ANOVA test to be applied to two fixed criteria. Should the null hypothesis be rejected, the Tukey and Bonferroni (*post hoc*) tests for multiple comparisons would be applied.

Table 1 shows the mean values and standard deviations for shear bond strength (MPa) for each group and experimental period. With the exception of T₀, when the specimens of groups AP and CO showed SBS values that were very near but higher than TB; the highest SBS values were observed in Group AP, followed by groups CO and TB.

ANOVA showed that there was statistically significant difference in the group factor ($p < 0.001$); and for the interaction between the time and group factors, ($p = 0.007$). However, it did not show differences for the time factor ($p = 0.453$).

By applying Tukey's multiple comparisons test for the group factor, it demonstrated that there

were statistically significant differences between the three experimental groups, with the highest SBS values found in the AP group, followed by the CO group and TB group, which exhibited the lowest values for this variable. The data from these tests can be seen in Figure 4.

To assess the qualitative variable "Adhesive Remnant Index" (ARI) the nonparametric Kruskal Wallis test was applied. If the null hypothesis, according to which all groups would show equal ARI values, were to be rejected, the comparison between the mean positions of the samples would be performed using the Dunn test for multiple comparisons in order to detect between which groups existed statistically significant differences. For all tests, a 0.05 level of confidence was adopted. The tests were conducted with the aid of SPSS 13.0 software for Windows and Graphpad InStat version 3.05. The non-parametric Kruskal Wallis test was applied and

Test	Group	Versus group	Difference between means	Standard error	Level of significance	95% confidence interval	
Tukey	AP	CO	4.4230	1.61479	0.018	0.6123	8.2336
	AP	TB	13.8099	1.59234	0.000	10.0522	17.5676
	CO	AP	-4.4230	1.61479	0.018	-8.2336	-.6123
	CO	TB	9.3869	1.52258	0.000	5.7939	12.9800
	TB	AP	-13.8099	1.59234	0.000	-17.5676	-10.0522
	TB	CO	-9.3869	1.52258	0.000	-12.9800	

Figure 4 - Tukey's test for multiple comparisons for the group factor.

Group	n	Median	Mean positions
Alpha Plast - T ₀	30	0	60.76
Concise - T ₀	30	1	82.60
Transbond - T ₀	30	2	153.48
Alpha Plast - T ₁	21	1	124.45
Concise - T ₁	24	2	151.73
Transbond - T ₁	26	1	126.17
Alpha Plast - T ₂	15	1	100.40
Concise - T ₂	24	1	82.16
Transbond - T ₂	25	2	140.24

Figure 5 - Frequency and median of values obtained for the Adhesive Remnant Index (ARI).

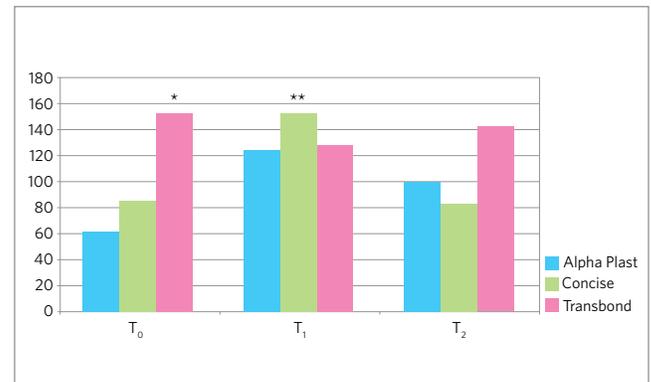


Figure 6 - Mean positions obtained for the Adhesive Remnant Index (ARI) for the Kruskal-Wallis test.

* Statistically significant difference ($p < 0.05$) found in comparing groups AP and CO.

* Statistically significant difference ($p < 0.05$) found when comparing to group CO.

yielded a value of $KW=65.79$, with 8 degrees of freedom, considered statistically significant ($p < 0.0001$). Thus, the null hypothesis (equal ARI for all groups) was rejected. Figure 5 shows the frequency and median of values obtained for ARI. The comparison between the sample mean positions was made by the Dunn multiple comparisons test, results can be seen in Tables 2 and 3. At T₀ the ARI for Group TB was statistically higher than those of groups AP and CO ($p < 0.05$). There were no statistically significant differences between the groups at T₁, whereas at T₂, the ARI for group TB was statistically higher than that of group C ($p < 0.05$), with no difference between the other groups, as can be observed in Figure 6.

In analyzing the behavior of group AP at different times, a statistically significant difference was found only between T₀ and T₁, while for group CO statistically significant differences were detected between T₀ and T₁, and also between T₁ and T₂.

There was no statistically significant difference between periods T₀ and T₂, and between the three periods assessed for group TB.

DISCUSSION

Bracket bond failures are a frequent occurrence in orthodontic practice. It is jeopardizing as it results in increased treatment time and operating costs, requiring a greater number of appointments¹¹ which can inconvenience the orthodontist and the patient alike. Identifying the cause of failure can help orthodontists reduce its occurrence, and instruct the patient on how to take proper care in order to avoid repeated bond failures and rebondings.¹² It is also important to understand the bonding mechanism, that involve at least two interfaces: The enamel/adhesive interface and bracket/adhesive interface.²

When faced with the need to rebond metal brackets, several options are available: Using the

Table 2 - Comparison between the mean positions by the Dunn multiple comparisons test.

	$T_0 \times T_1$		$T_0 \times T_2$		$T_1 \times T_2$	
	Difference between points	p value	Difference between points	p value	Difference between points	p value
Alpha Plast	-63.686	p<0.01	-39.633	p>0.05 ns	24.052	p>0.05 ns
Concise	-69.129	p<0.01	0.4333	p>0.05 ns	69.536	p<0.01
Transbond	27.31	p>0.05 ns	13.243	p>0.05 ns	-14.067	p>0.05 ns

Table 3 - Comparison between the mean positions by the Dunn multiple comparisons test.

	$T_0 \times T_0$		$T_1 \times T_1$		$T_2 \times T_2$	
	Difference between points	p value	Difference between points	p value	Difference between points	p value
Alpha Plast X Concise	-21.833	p>0.05 ns	-27.277	p>0.05 ns	18.233	p>0.05 ns
Alpha Plast X Transbond	-92.717	p<0.001	-1.721	p>0.05 ns	-39.84	p<0.05 ns
Concise X Transbond	70.883	p>0.001	-25.556	p>0.05 ns	58.073	p>0.05

same bracket that suffered debonding,^{6,7,13-17} using thermocycled brackets,^{5,18} or sandblasted recycled brackets,¹⁹ with or without primer^{20,21} or using new brackets.^{8,9,19,22} This fact establishes the necessity of further scientific research in the pursuit of the most appropriate method.

In this study, shear bond strength (SBS) tests were employed by following the recommendations found in the articles reviewed in the literature^{5,8,9,14,16,21,22} with loading speed of 0.5 mm/min. (ISO TR 11405) provided by a mechanical testing machine Shimadzu AG-I with a 10kN load.

The most widely cited light-cured orthodontic adhesive in the literature was Transbond XT, which seems to be the “gold standard.” It is a hybrid resin with a fair amount of filler. In this study, this adhesive achieved a shear bond strength (MPa) of 22.83 ± 7.10 in initial bonding; 23.20 ± 7.19 in the first rebonding and 25.85 ± 10.17 in the second rebonding. These values are close to those reported by Mui et al⁷, Liu et al,²³ Mondelli and Freitas¹⁷, and Pithon et al,²¹ who demonstrated Transbond XT’s adequate adhesion to dental structure. These findings differ

from the lower values found by Bishara et al^{8,9} due to the fact that the SBS reading was performed only 30 minutes after rebonding by these authors.

Concise Orthodontic Adhesive was cited in several studies.^{5,13,19,21} This adhesive contains 78% filler and is self-curing, for this reason it is the most often cited in studies assessing chemical-cured adhesives. In this study, this adhesive achieved a shear bond strength (MPa) of 36.74 ± 11.25 at initial bonding (T_0); 29.43 ± 6.54 in the first rebonding (T_1) and 32.48 ± 7.79 in the second rebonding (T_2). These values are close to those reported by Francisconi et al,⁵ Quick et al¹⁹ and Pithon et al²¹ who demonstrated that this adhesive also features adequate adhesion to dental structure.

In this study of repeated rebondings, unused brackets were used, as this clinical procedure has been common practice for several decades and due to the fact that there are few such studies in the literature.^{8,9} It is likely that this is due to the fact that the reuse of debonded^{6,7,13,14,19} and sandblasted^{15,24} brackets harks back to hard economic times when orthodontists used to import brackets and reuse meant cost reduction.

But this is no longer true and bracket recycling can affect bonding quality, as shown by Dickinson and Powers²⁵ as it deteriorates the bracket mesh base, thereby reducing shear bond strength (SBS).

SBS on rebonding remains controversial. In the view of some authors it is inferior to the first bonding²⁰ whereas others argue that it is comparable to⁶ or even superior to the original bonding.⁹ This study involved unused brackets and found statistically significant differences in SBS between bonding (T_0) and the first rebonding (T_1) for the Alpha Plast group, whereas for the Concise group the difference was significant between T_0 and T_1 as well as T_1 and T_2 . For the Transbond XT group, no statistically significant difference was found between the three periods, in disagreement with Wright and Powers²⁶ who found no loss in the SBS properties of this adhesive.

The ARI index used in this study was consistent with the results reported in the work of Hirani and Sheriff²⁰, which showed that the group bonded with Transbond XT had a score ranging between 1 and 2, in the same way, bondings made with Concise also had a score ranging between 1 and 2. Bondings performed with the Alpha Plast showed that ARI scores were concentrated between 0 and 1, indicating that part of the adhesive remained attached to the bracket and part to the tooth. However, this adhesive showed the greatest number of enamel fractures, compared with the other composite resins tested in this study.

The Alpha Plast adhesive system has seldom been used in laboratory experiments and was tested in this study because it is a self-curing adhesive widely used by orthodontists. It shows good bonding results as ascertained by the values achieved in

the tests of this study, with values of 34.18 ± 13.50 MPa for initial bonding, 40.28 ± 11.21 in the first rebonding and 40.71 ± 8.74 in the second rebonding. These values are statistically superior to the results found for the Concise and Transbond XT adhesives. This superiority can be due to the finding reported by Dickinson and Powers²⁵ namely, that composite resin filler content was shown *in vitro* to affect the adhesive force of brackets that rely on mechanical retention. Composites resins with a high amount of filler would provide improved adhesion to metal brackets when compared to low-filler composite resins. However, the elevated SBS of AP adhesive, caused a negative consequence of enamel fracture in most of the times, indicating the necessity of further studies by the manufacturer, in the attempt of keeping the adhesive properties while reducing biological consequences.

CONCLUSIONS

Given the methods used and results achieved in this *in vitro* study, it is reasonable to conclude that:

- 1 – There was a statistically significant difference in shear bond strength (MPa) between the Alpha Plast and Transbond XT groups, as well as between the Alpha Plast and Concise Orthodontic groups during bonding and repeated rebonding of new metal brackets.
- 2 – In rebonding with Transbond XT and Concise Orthodontic resins, bond failure sites are unpredictable, whereas with Alpha Plast bond failures occur predominantly at the enamel-adhesive interface, with higher frequency of dental enamel fractures.

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