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The effect of different reconditioning methods on bond strength of rebonded brackets: An in-vitro study

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Abstract

AIM: To evaluate the effect of three different reconditioning techniques on the shear bond strength (SBS) of rebonded brackets.

MATERIALS AND METHODS: Forty-five orthodontic brackets were bonded to human premolar teeth using Transbond™XT. After debonding, the samples were randomly assigned into equal groups to assess three techniques for the removal of residual adhesive from bracket bases: in Group A, each bracket base was sandblasted with aluminum oxide; in Group B₁, each base was cleaned superficially with a greenstone bur; and in Group B₂, the bases were thoroughly abraded with a greenstone bur. Subsequently, brackets were rebonded and the SBS and the adhesive remnant index (ARI) were determined. Data were analyzed using one-way analysis of variance (ANOVA), plus Tukey and Kruskal–Wallis post-hoc tests ($P \leq 0.05$).

RESULTS: The average SBSs were: Group A, 11.75 (± 4.83) MPa; Group B₁, 8.22 (± 4.01) MPa; and Group B₂, 7.54 (± 2.85) MPa. No statistically significant differences in SBS were found between Groups A and B₁ ($P = 0.051$) and Groups B₁ and B₂ ($P = 0.885$), but there was a significant difference between Groups A and B₂ ($P = 0.016$). Regarding ARI scores, there were statistically significant differences between Groups A and B₂ ($P < 0.001$) and between B₁ and B₂ ($P = 0.014$), but not between Groups A and B₁ ($P = 0.068$).

CONCLUSION: All reconditioning methods were found to have a positive effect, but the sandblasting technique performed best. Brackets reconditioned by sandblasting and superficial grinding mainly showed mixed-type failure, while in samples thoroughly reconditioned by greenstone bur, bonding failure occurred predominantly at the adhesive/bracket interface.

Keywords:

Adhesive remnant index, in-vitro, recycled brackets, shear bond strength

Introduction

Direct bonding of orthodontic brackets onto etched enamel surfaces has become an essential component of contemporary orthodontic treatment. In this context, bracket adhesion to a tooth surface should be strong enough to endure both occlusal forces and the stress applied by ligated archwires. Nevertheless, bond strength must not be so strong that it makes the debonding procedure difficult, with

a risk of damaging the bonded enamel surface.^[1,2] Thus, successful clinical bonding is generally agreed to involve a shear bond strength (SBS) in the range 5.9–7.8 MPa.^[2] In any event, the highest SBS of a bracket should be lower than the tensile strength of enamel, which is between 11 and 25 MPa.^[1,3]

Bracket bonding failure during orthodontic treatment is a moderately common observation, occurring in 0.5%–16% of cases, as documented by many researchers.^[4–6] Bond failure may arise from several factors, including clinician experience and skill,

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enamel morphology, bracket characteristic, patient performance, occlusal force, and the adhesive materials used.^[5-7] At times, clinicians might wish to deliberately debond a misplaced bracket and replace it in a more precise position.^[8]

Recycling orthodontic brackets for rebonding is preferred by some orthodontists for economic reasons.^[9] Commercial recycling is available, but it is time consuming and costly. Several practical and straightforward in-office bracket conditioning procedures have been investigated and recommended by others, including mechanical or thermal reconditioning methods, or a combination of both. A bracket base can be prepared with a rotary handpiece, a sandblast or a flame. The Buchman technique has been suggested as another reconditioning option, where adhesive remnants are removed by a flame, then sandblasting, followed by electropolishing.^[10] Several researchers have attempted to evaluate the procedures reported in the literature. For example, Wright and Powers^[11] investigated the effectiveness of a greenstone bur for the removal of adhesive residues from debonded brackets. They concluded that, although the SBS of the reconditioned brackets was lower than that of new brackets, it was insufficiently different to be clinically significant except in cases where a high adhesion strength was required, such as when a tooth occludes with a bracket in deep-bite cases. In another investigation, Egan *et al.*^[10] also reported that rebonding was a viable option; these authors used a greenstone bur to roughen the surface of a bracket without exposing the metal base. However, to date, there is no consensus on the most efficient and clinically acceptable recycling method. Furthermore, studies using a greenstone bur preparation method are scarce, and none has compared the SBS and adhesive failure of brackets that were recycled by either superficial or total adhesive removal. Therefore, the present study aimed to test the following null hypotheses:

- 1- The SBS of brackets recycled using sandblasting is similar to that of brackets prepared by either superficial or complete adhesive removal by greenstone bur;
- 2- The adhesive failure of brackets recycled using sandblasting is similar to the adhesive failure of brackets prepared by either superficial or total adhesive removal by greenstone bur.

Materials and Methods

This prospective experimental investigation was granted ethical approval by the Ethics Committee of Egas Moniz -Cooperativa de Ensino Superior. The sample size was determined according to Wongsamut *et al.*^[12] Thus, for an alpha error of 5% and a power of

95%, a minimum of 12 specimens should be included in each group. However, the number of specimens in each group was increased to 15 to compensate for any bracket damage or bonding failure. A total of 45 ($N = 45$) human premolar teeth were selected from the human dental bank of the university. The selected teeth were extracted within 6 months of the investigation. All teeth had an intact enamel, no fractures, no hypoplasia, no previous endodontic treatment or restoration. Following tooth extraction, tissue debris and blood traces were removed with a Gracey 5/6 curette under running water. Disinfection was carried out by maintaining the teeth for 1 week in a 1% bacteriostatic/bacteriocidal solution of chloramine-T trihydrate. Subsequently, the teeth were kept in distilled water at 4°C, which was changed every 2 months to avoid sample degradation (Standard ISO/TS 11405:201516).^[13] The teeth were then installed on a cylindrical acrylic block, showing only the crown part.

Bonding/debonding the brackets

The MBT premolar brackets (0.022 × 0.028, Victory series; 3M Unitek) were bonded using the Transbond™ XT (3M Unitek) primer-adhesive system. The bonding protocol was modified by not etching the enamel surface with phosphoric acid (35%), thereby facilitating detachment of the adhesive from the enamel surface during the first debonding and consequently allowing the adhesive to completely cover the base of the bracket when it was used in further treatment. Before bonding, the teeth were pumiced with a nonfluoridated paste using a rubber cup. A thin uniform layer of primer was applied to the vestibular premolar surface and then gently dried with an oil-free air source. Transbond™ XT paste was placed on the bracket bases before positioning them accurately and firmly on the tooth surface with a bracket tweezer. Any excess adhesive was removed from around the bracket base. The adhesive was then light-cured for 6 seconds (3 seconds mesial and 3 seconds distal to the bracket) with a photopolymerized (3M Ortholux™) Luminous Curing Light with a light intensity of 1600 mW/cm² at a distance of 3 mm, according to the manufacturer's instructions.

Subsequently, the brackets were stored within a universal incubator oven (Mettmert® INE 4002), at 37°C for 24 h (Norma ISO/TS 11405:2015).^[13] Next, the brackets were detached from the premolars using an orthodontic tweezer and the samples were randomly divided into three groups (15 teeth per group). They were subjected to a reconditioning method to remove adhesive remnants as follows:

Group A—the bracket base was sandblasted with 30 µm aluminium oxide particles (Rocatec™) at a distance of 10 mm from the base of the bracket until all composite resin remnants had been removed.^[14]

Group B₁—the bracket base was superficially cleaned with a greenstone bur (ShofuINC Dura-Green Stones) at a velocity of 25,000 rotation/min.^[13] The bur was applied to the bracket base with light pressure for 25 s to remove the superficial adhesive layer.

Group B₂—the bracket base was cleaned with the exact specifications and the same technique used in Group B₁, except that the pressure applied on the greenstone bur was greater (moderate) to eliminate all the adhesive remnants. Subsequently, the brackets in all three groups were rebonded after conditioning the enamel surface with phosphoric acid.

The SBS test was undertaken 24 h later.^[6,15] During this period, the specimens were maintained in deionized water.^[3] The debonding test was evaluated for each bracket individually using a Universal Autograph AG-IS machine.^[14] Each specimen tested was premounted on a customized acrylic resin block (Schütz Futura Self).^[16] The acrylic blocks were positioned and fixed in the testing machine to maintain the bracket base parallel to the direction of the applied shear force. A flattened steel rod applied the shear force to the bracket at a crosshead speed of 1 mm/min speed, and the SBS values at the bracket-bonding failure point were registered using a PC connected to the testing machine.^[17] Click or tap here to enter text. The SBS values were evaluated and computed in MPa by dividing the force by the area of the bracket base. The site of bond failure was determined using an optical microscope (Leica MZ6) at 10x magnification, and the adhesive remnant index (ARI) was used to determine the amount of adhesive left on the tooth surface after debonding. The ARI score categorizes the quantity of remnant adhesive as follows: score 0, when there is no composite resin left on the tooth surface; score 1, less than half of the composite resin left on the tooth surface; score 2, more than half of composite resin left on the tooth surface; score 3, all composite resin left on the tooth with a marked imprint of the bracket base.

Statistical analysis

The IBM software Statistical Package for Social Science (SPSS®) v. 26 was used. Adequate normality and homoscedasticity of the SBS data were confirmed. One-way ANOVA was undertaken to compare the mean SBS values among the three groups, followed by a post-hoc Tukey test for pair-wise multiple comparisons. The ARI score was compared across the groups using the Kruskal-Wallis test, followed by multiple comparisons under Bonferroni correction. The significance level was set at 5% ($P \leq 0.05$).

Results

The mean ($\pm$ SD) SBS of Group A was 11.75 ($\pm$ 4.83) MPa, Group B₁ 8.22 ($\pm$ 4.01) MPa, and Group B₂ 7.54 ($\pm$ 2.85)

MPa [Table 1]. A significant difference was found when considering the mean SBS values of the three examined groups ($P = 0.013$, one-way ANOVA). Subsequently, a post-hoc pair-wise Tukey test showed the existence of statistically significant discrepancies between Group A and B₂ ($P = 0.016$). The statistical differences between Group A and B₁ ($P = 0.051$), and Group B₁ and B₂ ($P = 0.885$) were found to be nonsignificant [Table 2].

Mode of bracket failure

The distribution of the ARI scores of the three groups is displayed in Table 3. Group A was the most homogeneous, where 14 out of the 15 cases (93.3%) showed a mixed-type failure at the enamel/adhesive interface (score 2), and only one case (6.7%) exhibited an ARI level of 3, meaning that all of the adhesive remained on the enamel surface. On the other hand, the specimens in Group B₁ and Group B₂ were more heterogeneous. In Group B₁, failure was predominantly mixed: 10 cases were classified as ARI score 1 (66.7%), three cases as score 2 (13.3%), while only two specimens had an ARI score of 3 (20%). In Group B₂, the predominant type of failure was at the adhesive/bracket interface (i.e., ARI score 3; 11 specimens, 73.3%); the remaining four samples (26.7%) were of the mixed failure type. Table 4 shows the ARI score comparison for the three groups, as revealed by a Kruskal-Wallis test. There were significant differences ($P < 0.001$)

Table 1: Mean (MPa), standard deviation (SD) and minimum and maximum values of the shear bond strength (SBS) values recorded for the three groups. P value revealed by one-way ANOVA

Group	n	Mean	SD	Minimum	Maximum	P
A	15	11.7	4.8	6.3	21.5	0.013
B ₁	15	8.2	4.0	2.9	14.7	
B ₂	15	7.5	2.8	2.6	13.0	

Table 2: Multiple statistical comparison of the shear bond strength (SBS) mean values among the three groups, as evidenced by the post-hoc Tukey test

Groups	P
A-B ₁	0.051
A-B ₂	0.016
B ₁ -B ₂	0.885

Table 3: Distribution of the type of failure according to the adhesive remanent index (ARI) scores among the three examined groups

Group	ARI score			
	0	1	2	3
A	0	0	14	1
B ₁	0	10	3	2
B ₂	0	1	3	11
Total	0	11	20	14

Table 4: Multiple statistical comparison for the ARI score distribution of the three experimental groups as revealed by the Kruskal-Wallis test with Bonferroni correction

Groups	P
A-B ₁	0.068
A-B ₂	<0.001
B ₁ -B ₂	0.014

between Group A (sandblasted) and Group B2 (total removal of adhesive by greenstone bur), and between Groups B1 and B2 ($P = 0.014$). In contrast, the ARI scores of Groups A and B1 [Table 4] were not found to be significantly different ($P = 0.068$).

Discussion

Reconditioning an orthodontic bracket requires the elimination of the remnants of bonding material from the bracket base without distorting the delicate mesh or altering the bracket parameters.^[18] In clinical terms, the optimum SBS for an orthodontic bracket has yet to be determined. Ideally, brackets should be easily bonded, remain in place without bond failure until the orthodontic treatment is complete, and then be amenable to debonding without causing any harm to the enamel surface.^[15] Reynold^[2] reported that the optimal SBS of a new bracket ranges between 5.9 and 7.8 MPa. Nevertheless, the highest bond strength should be lower than the SBS of enamel (11–25 MPa). Our study demonstrates that the mean SBSs of reconditioned brackets after all three of the reconditioning techniques tested were adequate for clinical use: sandblasting, 11.75 MPa; superficial adhesive removal with greenstone bur, 8.22 MPa; and complete adhesive removal with greenstone bur, 7.45 MPa.

Many investigators have attempted to identify the most effective reconditioning methods for the recycling of orthodontic brackets,^[18-23] but there is currently no consensus of opinion. In their review of 12 research studies, Grazioli *et al.*^[24] came to the conclusion that an erbium-doped yttrium aluminum garnet (Er: YAG) laser is superior to other methods tried for preparing recycled brackets. However, the same authors highlighted the existence of significant heterogeneity among the studies reviewed, most probably due to the lack of standardization of techniques used to evaluate SBS. Another systematic review and meta-analysis of sixteen investigations^[9] concluded that the SBS of sandblasted brackets appears to be clinically comparable to that of a new bracket. Among investigations similar to the present study, Faltermeier and Behr^[25] and Basudan and Al-Emran^[20] observed a significant reduction in the SBS of recycled brackets prepared by either thermal or chemical techniques,

or by surface or total abrasion with greenstone bur. In contrast, Grabouski *et al.*^[25] reported an equivalent SBS in new and rebonded brackets prepared by carbide bur followed by sandblasting. Quick *et al.*^[26] analyzed six recycling methods where the specimens included in four of the groups were first flamed and then either sandblasted, ultrasonically prepared, ultrasonically conditioned followed by application of silane, or rebonded without additional treatment. Of the two remaining groups, one was sandblasted, whereas the brackets in the other were roughened with a greenstone bur. Subsequently, the brackets were rebonded to premolar teeth following the re-preparation of the enamel surfaces. Quick *et al.*^[26] concluded that the sandblasting technique was significantly superior to the other methods and resulted in a SBS similar to that of a new bracket, while the greenstone bur preparation showed the second lowest SBS among the six groups after the flamed-only group. However, Quick *et al.*^[26] found that the discoloration of the flamed brackets was a disadvantage if flaming was not followed by electropolishing. Also, the bracket metal was softened by the heating procedure and became more susceptible to masticatory damage. Correspondingly, Chetan *et al.*^[18] noticed that sandblasting a debonded bracket offers a significantly better SBS compared to other conditioning methods they examined (greenstone, direct flame, flame followed by ultrasonic cleaning, and sandblasting). Al Maaithah *et al.*^[19] Click or tap here to enter text. came to a similar conclusion for the three conditioning techniques they investigated (carbide bur, ultrasonic scaler, and sandblasting), but they favored the ultrasonic scaler method due to its availability and simplicity. The results of our study support Chetan *et al.*^[18] Click or tap here to enter text. and Grabouski *et al.*^[27] that is, the sandblasting preparation technique is superior to the other conditioning methods we tested, giving a higher SBS than superficial or total adhesive removal with a greenstone bur. Nevertheless, our results showed that statistically significant differences were detected only between the sandblasting method and that involving total removal of the resin. The lower SBS observed when complete removal of the adhesive was undertaken is not unexpected, as removing adhesive completely with a greenstone bur also removes undercuts from the mesh covering the bracket base. However, our study revealed that using a greenstone bur for superficial cleaning remains an acceptable and convenient option with a reasonable successful rate. Within this context, we can partially reject the first null hypothesis and conclude that, while the SBS of brackets recycled using sandblasting is similar to that of SBS brackets prepared by superficial adhesive removal by greenstone bur, the sandblasting technique was significantly superior to the total removal of adhesive by greenstone bur.

Mode of bracket failure

Durable bracket bonding that lasts until the end of orthodontic treatment significantly enhances treatment outcome and minimizes wasted clinical time. However, if the adhesion is too strong, this might complicate bracket removal at the end of treatment and cause cracks in the tooth enamel. Therefore, a mixed-type bond failure where adhesive is retained on both the bracket and enamel surfaces might be preferable to avoid damage to the enamel. Elimination of adhesive remnants from the enamel surface can be safely performed with multilaminated slow-speed and polishing rubber-cup burs.^[8] In our study, the majority of cases treated by sandblasting and partial removal of adhesive by greenstone bur showed a mixed-type failure, because there was less adhesive to remove from the tooth surface; therefore, this might be considered more beneficial to the enamel than the other bond-failure groups.^[23]

The majority of Group B₂ samples, which were treated by complete elimination of the adhesive prior to debonding, showed bond failure at the bracket base level (73.3%), with the remainder showing mixed-type failure (26.7%). The failure in Group B₂ was most probably associated with the flattening of the bracket mesh by the pressure of the greenstone bur; therefore, the resin remained on the tooth surface. ARI score differences between Group B₂ and the other two groups were statistically significant. In contrast, the ARI score differences between Group A and Group B1 were not statistically significant ($P = 0.068$). Therefore, the second null hypothesis was rejected and we can conclude that the adhesive failure rates of brackets treated using either sandblasting or partial removal of resin by greenstone bur were similar, while the only significant difference was between the sandblasting technique and the complete removal of resin by greenstone bur. These results indicate that the type of reconditioning used on the bracket base did influence any bond failure that might occur.

This study also revealed that there were significant differences between the mean SBS values of the three preparation methods, such that the first null hypothesis could be rejected, and the related conclusion drawn from this study is that there was a significant discrepancy between Group A (sandblasted) and Group B₂ (complete removal of adhesive by greenstone). However, all the techniques we examined showed mean SBS values that were equal to or greater than clinically acceptable levels (6–8 MPa).

The aim of the present study was to evaluate the SBS of the three reconditioning techniques. A further evaluation of the impact of the reconditioning techniques on the susceptibility of the brackets to metal corrosion has yet to be explored. In considering our results, it is important

to emphasize that this was a laboratory study; therefore, caution is recommended when applying these findings to clinical settings.^[18]

Conclusions

- All three reconditioning methods (sandblasting, superficial and total adhesive removal by greenstone bur) tested on stainless steel orthodontic brackets were sufficiently effective to be consistent with clinical use;
- The sandblasting reconditioning technique showed the highest SBS values among the three methods. However, significant differences were observed only between sandblasting and complete elimination of adhesive from the bracket base;
- The ARI test showed that complete elimination of adhesive from the bracket base using a greenstone bur was significantly less favorable in terms of bracket failure than sandblasting and superficial adhesive removal using a greenstone bur.

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Conflicts of interest

There are no conflicts of interest.

References

1. Tay F, Carvalho R, Sano H. Effect of smear layers on the bonding of a self-etching primer to dentin. *J Adhesive Dent* 2000;2:99-116.
2. Reynolds IR, von Fraunhofer JA. Direct bonding of orthodontic brackets--A comparative study of adhesives. *Br J Orthod* 1976;3:143-6.
3. Bishara SE, Laffoon JF, VonWald L, Warren JJ. The effect of repeated bonding on the shear bond strength of different orthodontic adhesives. *Am J Orthod Dentofac Orthop* 2002;121:521-5.
4. Bakhadher W, Halawany H, Talic N, Abraham N, Jacob V. Factors affecting the shear bond strength of orthodontic brackets-a review of *in vitro* studies. *Acta Medica* 2015;58:43-8.
5. Murray S, Hobson R. Comparison of *in vivo* and *in vitro* shear bond strength. *Am J Orthod Dentofac Orthop* 2003;123:2-9.
6. Mandall NA, Hickman J, Macfarlane TV, Mattick RC, Millett DT, Worthington HV. Adhesives for fixed orthodontic brackets. *Cochrane Database Syst Rev* 2003;CD002282.
7. Adolffson U, Larsson E, Ögaard B. Bond failure of a no-mix adhesive during orthodontic treatment. *Am J Orthod Dentofac Orthop* 2002;122:277-81.
8. Meira Cardoso LA, Valdrighi HC, Filho MV, Correr AB. Effect of adhesive remnant removal on enamel topography after bracket debonding. *Dent Press Orthod J* 2014;19:105-12.
9. Anita P, Kailasam V. Effect of sandblasting on the shear bond strength of recycled metal brackets: A systematic review and meta-analysis of in-vitro studies. *Int Orthod* 2021;19:377-88.
10. Egan F, Alexander S, Cartwright G. Bond strength of rebonded orthodontic brackets. *Am J Orthod Dentofac Orthop* 1996;109:64-70.
11. Wright W, Powers J. *In vitro* tensile bond strength of reconditioned brackets. *Am J Orthod* 1985;87:247-52.
12. Wongsamut W, Satrawaha S. Surface modification for bonding

- between amalgam and orthodontic brackets. J Orthod Sci 2017;6:129-35.
13. ISO - ISO/TS 11405:2015 - Dentistry — Testing of adhesion to tooth structure. <https://www.iso.org/standard/62898.html>. [Last accessed on 2022 Jul 12].
14. de Moraes E, Romano L, Sobrinho LC, Bortolazzo Correr A, Borges De Araújo Magnani MB. Shear bond strength of composites using an adhesion booster. Dental Press J Orthod 2011;16:104-10.
15. Gange P. The evolution of bonding in orthodontics. Am J Orthod Dentofac Orthop 2015;147:S56-63.
16. Vinagre A, Messias A, Gomes M, Costa A, Ramos JC. Effect of time on shear bond strength of four orthodontic adhesive systems effect of time on shear bond strength of four orthodontic adhesive systems. Rev Port Estomatol Med Dent Cir Maxilofac 2014;55:142-151.
17. Alessandri Bonetti G, Zanarini M, Incerti Parenti S, Lattuca M, Marchionni S, Gatto MR. Evaluation of enamel surfaces after bracket debonding: An in-vivo study with scanning electron microscopy. Am J Orthod Dentofac Orthop 2011;140:696-702.
18. Chetan G, M Reddy M. Comparative evaluation of four office reconditioning methods for orthodontic stainless steel brackets on shear bond strength—An *in vitro* study. Ann Essences Dent 2011;3:6-13.
19. Maaitah E al, Alomari S, Alhaija E. The effect of different bracket base cleaning method on shear bond strength of rebonded brackets. Journal of Contemporary Dentistry 2013;14:866-70.
20. Basudan AM, Al-Emran SE. The effects of in-office reconditioning on the morphology of slots and bases of stainless steel brackets and on the shear/peel bond strength. J Orthod 2014;28:231-6.
21. Yassaei S, Aghili H, KhanPayeh E, Goldani Moghadam M. Comparison of shear bond strength of rebonded brackets with four methods of adhesive removal. Lasers Med Sci 2014;29:1563-8.
22. Endo T, Ozoe R, Shinkai K, Shimomura J, Katoh Y, Shimooka S. Comparison of shear bond strengths of orthodontic brackets bonded to deciduous and permanent teeth. Am J Orthod Dentofac Orthop 2008;134:198-202.
23. Knösel M, Mattysek S, Jung K, Sadat-Khonsari R, Kubein-Meesenburg D, Bauss O, *et al.* Impulse debracketing compared to conventional debonding: Extent of enamel damage, adhesive residues and the need for postprocessing. Angle Orthod 2010;80:1036-44.
24. Grazioli G, Hardan L, Bourgi R, Nakanishi L, Amm E, Zarow M, *et al.* Residual adhesive removal methods for rebonding of debonded orthodontic metal brackets: Systematic review and meta-analysis. Materials 2021;14:6120. doi: 10.3390/ma14206120.
25. Faltermeier A, Behr M. Effect of bracket base conditioning. Am J Orthod Dentofac Orthop 2009;135:12.e1-5.
26. Quick A, Harris A, Joseph V. Office reconditioning of stainless steel orthodontic attachments. Eur J Orthod 2005;27:231-6.
27. Grabouski J, Staley R, Jakobsen J. The effect of microetching on the bond strength of metal brackets when bonded to previously bonded teeth: An *in vitro* study. Am J Orthod Dentofac Orthop 1998;114:452-60.