The effect of repeated bracket recycling on the shear bond strength of different orthodontic adhesives

Nádia Lunardi[1]; Gustavo Hauber Gameiro[2*]; Maria Beatriz Borges de Araújo Magnani[3]; Darcy Flávio Nouer[4*]; Vânia Célia Vieira de Siqueira[3*]; Simonides Consani[5*]; João Sarmento Pereira-Neto[3*]

[1]*DDS, MS, Private Practice*
[2]*DDS, MS, PhD student, Department of Pediatric Dentistry, Orthodontics Division*
[3]*DDS, MS, PhD, Assistant Professor, Department of Pediatric Dentistry, Orthodontics Division*
[4]*DDS, MS, PhD, Professor, Department of Pediatric Dentistry, Orthodontics Division*
[5]*DDS, MS, PhD Professor, Department of Restorative Dentistry, Dental Materials Division*
[*]*Piracicaba Dental School, University of Campinas, Piracicaba, SP, Brazil*

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Abstract

Aim: The aim of this study was to evaluate the effect of two consecutive recycling procedures on the shear bond strength of different orthodontic adhesives. **Methods:** Edgewise brackets were bonded to the buccal surfaces of 40 bovine incisors using the following bonding materials: Concise (group I), Transbond XT (group II), Smart Bond (group III) and Fuji Ortho (group IV). The teeth were stored in water at 37°C for 24 h, thermocycled between 5 and 55°C, and debonded using an Instron machine at a crosshead speed of 0.5 mm/min. In all groups, the bonded brackets were detached and rebonded after recycling by 50-µm particle aluminum oxide blasting. After the second recording of retentive strengths, the recycling procedure, the rebonding and the shear bond strength test were repeated. Data were analyzed statistically by ANOVA and Tukey's test at 5% significance level. **Results:** The results showed that repeated recycling did not interfere in retention of brackets, regardless of the adhesive used. The highest shear bond strength values were obtained after bonding with Transbond XT, independent of the recycling procedure. **Conclusion:** Repeated bracket recycling using 50-µm aluminum oxide particle air abrasion did not affect the shear bond strength of metallic brackets bonded with different orthodontic adhesives.

Key Words: orthodontic brackets, bonding, recycling, aluminum oxide air abrasion.

Introduction

One problem that clinicians face during treatment is bracket failure. This is usually the consequence of either a patient's accidentally applying inappropriate force to the bracket or a poor bonding technique. Thus, a significant number of teeth must be rebonded in a busy orthodontic practice. One solution is to recycle the brackets[1]. The recycling process basically consists in removing bonding agent remnants from the bracket base, thus allowing the brackets to be reused without causing damage to the retention mesh and preserving its retentive characteristics[2]. Although the clinical use may produce small distortions on the brackets, removal phase is responsible for most distortions and damages observed[3]. Bracket recycling can be performed either in the dental office (immediate method) or by specialized companies without altering the slot positions[4].

Two methods are commonly used for industrial bracket recycling: 1) heat application to burn the bonding agent followed by electrolytic polishing for oxide removal; 2) use of chemical solvents to dissolve the bonding agent in combination with high frequency vibrations and electrochemical polishing[5-7]. However, these are impractical to perform at the chairside. Thus, several in-office bracket reconditioning methods have been introduced[1,8]. Immediate recycling of debonded brackets can be performed using silicon carbide stone grinding or aluminum-oxide blasting, which enhances bracket bonding to tooth structure by producing micromechanical retention on base surface. This process increases the area of composite bonding, which is essentially mechanical due to the micro-asperity of the bracket mesh. In spite of its increasingly widespread use for recycling purposes, aluminum-oxide blasting technique was originally intended

Correspondence to:
João Sarmento Pereira-Neto
Faculdade de Odontologia de Piracicaba – UNICAMP
Av. Limeira 901 C.P. 52, CEP 13414-903, Piracicaba, SP, Brasil
Phone.: +55-19-2106-5288
Fax.: +55-19-21065218
e-mail: sarmento@fop.unicamp.br

to enhance the mechanical retention of new brackets and improve bracket bonding to restored teeth as well as to prepare the enamel surface[8-9].

Several *in vitro* studies evaluating the effect of recycling on bracket bond strength have shown that reconditioning produces a reduction in bond strength, which is statistically significant compared to new brackets[10-14]. However, one must take in consideration that the effects of recycling depend on the type of reconditioning process used, the type of steel from which the bracket is constructed, and whether the bracket has a mesh pad or a non-mesh undercut integral pad[15]. Tavarez et al.[16] have shown that brackets recycled by aluminum oxide blasting had similar shear bond strength when compared with new ones. Moreover, the bond strength values obtained after this recycling procedure were consistently higher than those obtained by an industrial process at a specialized company and those obtained by silicon carbide stone grinding.

The reduced cost of using recycled brackets represents a significant financial advantage when bonding orthodontic brackets. To date, however, the bonding performance of brackets submitted to repeated recycling has not been investigated. Thus, the purpose of the present study was to evaluate *in vitro* the effect of two consecutive recycling procedures on the shear bond strength of different orthodontic adhesives.

Material and Methods

Forty freshly extracted bovine permanent mandibular incisors were collected, cleaned of soft tissue and stored in a saline, which was renewed every 7 days, and maintained under refrigeration at 4ºC. The criteria for tooth selection included intact buccal enamel, no pretreatment with chemical agents (eg, hydrogen peroxide), no cracks caused by the extraction forceps and no caries.

The teeth were embedded in chemically activated acrylic resin (Vipi Flash; Dentalvipi, Pirassununga, SP, Brazil) using PVC rings (Tigre, Cotia, SP, Brazil) as moulds (20 mm in internal diameter; 20 mm in height), leaving only the crowns exposed. The buccal surfaces were cleaned with water/pumice slurry in Robinson bristle brushes (KG Sorensen, Rio de Janeiro, RJ, Brazil) at slow speed for 15 s, rinsed and dried with an air stream for 10 s each. The Robinson brushes were replaced for new ones every five teeth to maintain the same mechanical cleaning action for all specimens. Forty Edgewise metallic brackets for central incisors (Ultraminitrim-Dentaurum, Ispringen, Germany) without angulation or torque were used.

The teeth were randomly divided into 4 groups. The brackets were bonded to the teeth according to protocols following the manufacturer's instructions, except for Group IV, as described in the discussion section:

Group I - Bonding protocol with Concise Orthodontic (3M Dental Products, St. Paul, MN, USA): 10 teeth were etched with 37% phosphoric acid gel for 30 s, washed with running water for 30 s, and dried for 20 s with oil free light compressed air jets. Before bonding, a thin layer of adhesive was applied to the etched area. The bracket was applied to the tooth with a constant force, and the excessive material was carefully removed. A 5-min period was allowed for self-polymerization

Group II - Bonding protocol with Transbond XT (3M Unitek, Monrovia, CA, USA):10 teeth were etched with 37% phosphoric acid gel for 30 s. The teeth were thoroughly washed (30 s) and air dried (20 s). The sealant was applied, and the brackets were then bonded and light-cured with a halogen light-curing unit (3M Unitek, Sumaré, SP, Brazil) for 20 s on the mesial side and 20 s on the distal side (total curing time, 40 s).

Group III - Bonding protocol with SmartBond adhesive system (Gestenco International, Göthenburg, Sweden): 10 teeth were etched with 35% phosphoric acid for 10 s followed by thorough washing (30 s) and drying (20 s). A moist cotton roll was used to wet the enamel surface before the adhesive was applied. Once the SmartBond adhesive came into contact with the wet enamel surface, the clinician had 3 to 5 s to adjust the placement of the bracket before the adhesive starts to set within 3 to 5 min.

Group IV - Bonding protocol with Fuji Ortho LC (Gc Corporation, Tokyo, Japan): 10 teeth were etched with 37% phosphoric acid for 30 s, washed with running water for 30 s, and dried for 20 s. Each tooth was then wiped with a moist cotton roll to ensure that the bonding surface was not desiccated, and excess water was removed. Fuji Ortho LC RMGI capsule was triturated for 10 s and then applied to the bracket without bubbles or voids. The bracket was applied to the tooth with a constant force, and the surrounding flash was carefully removed. The adhesive was light-cured with a halogen light-curing unit (3M Unitek, Sumaré, Brazil) for 20 s on the mesial side and 20 s on the distal side (total curing time, 40 s).

After bonding, the mounted teeth were thermocycled between 5°C and 55°C for 500 cycles. The exposure to each bath was 20 s, and the transfer time between the two baths was 5-10 s. Debonding was performed at room temperature.

The brackets were debonded using a universal testing machine (Instron Corp., Canton, Mass) at a crosshead speed of 0.5 mm/min. The samples were fixed to the testing machine by wire rings (0.019- × 0.025-inch) attached to the bracket slot and to the machine's clamps (Figure 1). In this test, however, the resulting stress in the tooth-bracket bonding zone represented the shear bond strength. The rings were replaced with new ones for every 10 shear tests. The shear bond strength values were obtained in kgf and were divided by the bracket's area to convert them into MPa.

The bases of the brackets were sandblasted with 90µm diameter particle aluminum oxide air-abrasion (Bio-Art, São Carlos, SP, Brazil) for 15 s. A 10-mm distance was kept between the device tip and the bracket base[17]. After

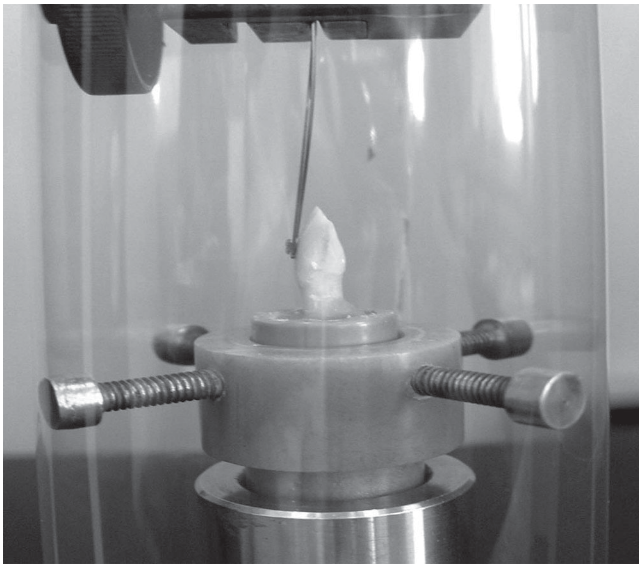

Fig. 1. *Shear strength testing in the Instron machine.*

each debonding, all visible residual adhesive was removed with a multiblade carbide burs (9114F; KG Sorensen) at low speed, which were replaced by new ones every 5 teeth. After the second recording of retentive strengths, the recycling procedure, the rebonding and the shear bond strength test were repeated.

Since the data had a normal distribution (Shapiro-Wilk test), the results of the shear bond strength were submitted to analysis of variance and Tukey test in order to compare the 4 adhesives at each bonding/debonding sequence (1st and 2nd recycling) and to determine whether significant differences existed in the shear bond strength of the 2 recycling procedures s within each adhesive. The level of significance was set at 5%.

The brackets were examined with a scanning electron microscope (LEO 435 VP; Leo Electron Microscopy Ltd., Cambridge, England) to observe the base meshes before and after recycling procedures.

Results

The descriptive statistics for the shear bond strength at the 2 recycling procedures for the 4 adhesives are presented in the Table 1. Within each adhesive type, no statistically significant differences ($p<0.05$) were found between new brackets and recycled ones for both 1st and 2nd recycling procedures.

The comparisons among the 4 adhesives at each recycling procedure indicated significant differences. Transbond had a significantly higher shear bond strength than that that of the other adhesives at each bonding/debonding sequence, except for Transbond XT versus Smartbond in new brackets, and Transbond XT versus Concise in recycled brackets -2nd recycling (Table 1). The SEM micrographs of each studied group are shown in Figures 2 to 5.

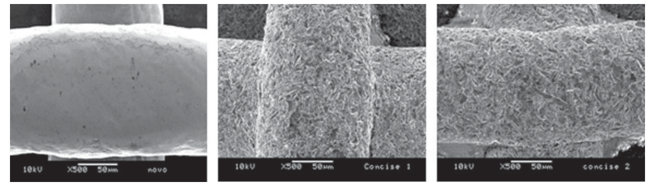

Fig. 2. *Scanning electron micrographs of a bracket base (A) after first (B) and second recycling (C) with aluminum oxide blasting. Roughness of recycled bracket provided significant mechanical retention during bonding process (in this example, brackets were bonded with Concise - original magnification x500)*

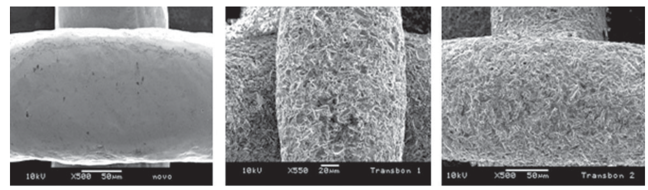

Fig. 3 - *Scanning electron micrographs of a bracket base (A) after first (B) and second recycling (C) with aluminum oxide blasting. Roughness of recycled bracket provided significant mechanical retention during bonding process (in this example, brackets were bonded with Transbond - original magnification x500)*

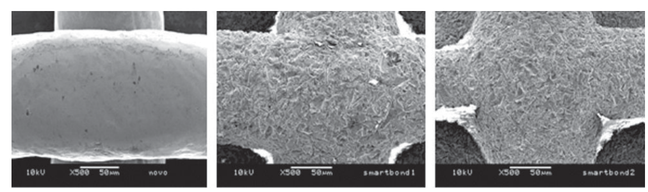

Fig. 4 - *Scanning electron micrographs of a bracket base (A) after first (B) and second recycling (C) with aluminum oxide blasting. Roughness of recycled bracket provided significant mechanical retention during bonding process (in this example, brackets were bonded with SmartBond - original magnification x500)*

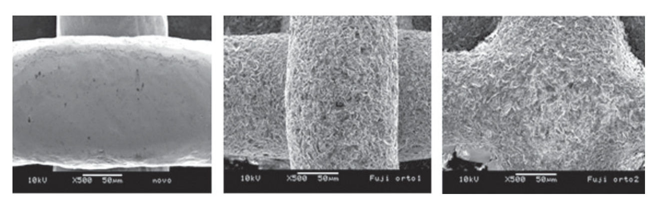

Fig. 5 - *Scanning electron micrographs of a bracket base (A) after first (B) and second recycling (C) with aluminum oxide blasting. Roughness of recycled bracket provided significant mechanical retention during bonding process (in this example, brackets were bonded with Fuji Ortho LC - original magnification x500)*

Discussion

Bond failure during orthodontic treatment is relatively frequent and undesirable. As a result, the shear bond strength of new and recycled brackets has been a subject of great interest in orthodontic research. The present investigation demonstrated that, when using four different orthodontic adhesives, the shear bond strength of recycled brackets was not significantly different from that new ones. Also, the repeated recycling did not affect the shear bond strength

Table 1 - Descriptive statistics and results of ANOVA/Tukey tests comparing shear bond strength (mean in MPa and SD) within and among the 4 adhesive systems after repeated recycling procedures

Adhesive system	New brackets	1st Recycling	2nd Recycling
Concise	4.168 (2.397) b	4.821 (2.328) b	5.769 (3.21) ab
Transbond	8.177 (4.612) a	8.460 (3.632) a	8.101 (2.055) a
Smartbond	4.808 (2.546) ab	4.468 (1.857) b	3.434 (1.989) b
Fuji Ortho	3.013 (1.352) b	4.559 (2.688) b	3.740 (1.608) b

Different letters indicate statistically significant difference within and among materials at each debonding sequence ($p < 0.05$)

when two recycling procedures were compared with the first bonding strength. Although some studies have shown that recycling of bonded and rebonded orthodontic attachments adversely affect the shear bond strengths[10-14], it is important to note that the effects of recycling depend fundamentally on the type of reconditioning process used. This fact can be observed in the study of Tavarez et al.[16] in which brackets recycled by aluminum oxide blasting had similar shear bond strength when compared with new ones, and the bond strength values obtained after 90-µm particle aluminum oxide blasting were consistently higher than those obtained by an industrial process at a specialized company or by silicon carbide stone grinding. Several studies have reported that sandblasting bracket bases greatly increases their retentive surface which produces a significant reduction in the probability of failure relative to the non-sandblasted samples[8,18]. In a previous study, it was reported that sandblasting the mesh-base of the stainless steel bracket for 3 s increased the bond strength of the conventional glass-ionomer cements to a level that may be clinically acceptable[8]. In this study, the time spent for bracket recycling with aluminum oxide air-abrasion was of 15 s and a10-mm distance was kept between the device tip and the bracket base. The time and distance settings were used to provide data directly comparable to those of other studies[16,17]. The good mechanical retention between the enamel surface and the air-abraded recycled brackets is probably due to the fact that this method creates an effective microroughened surface on the bracket base, which increases the area available for composite bonding in comparison to the control brackets[19] (Figures 2 to 5).

Because orthodontic adhesives are routinely subjected to thermal changes in the oral cavity, it is important to determine whether such temperature variations introduce stresses in the adhesive that might influence bond strength. Some investigators found that the shear bond strength of resin-modified glass ionomers is clinically acceptable following thermocycling[20-22]. whereas others concluded that bond strengths were acceptable only when phosphoric acid is used as an etchant[23]. In the present study, the tooth substrates were submitted to thermocycling and the phosphoric acid was used before bonding with Fuji Ortho LC to simulate the clinical condition when this protocol is commonly used.

Examining the base of the bracket with the scanning electron microscope (SEM) suggested that the amount of mechanical retention created by the 50µm particle aluminum oxide blasting could be responsible for the similar shear bond strengths observed in recycled and new brackets, even after two recycling procedures. Bishara et al.[24] showed that rebonded teeth have significantly lower bond strength because of the residual adhesive on the enamel surface. The residual adhesive was present even after the surface was cleaned with the finishing bur and the enamel surface regained its gloss. Although the residual adhesive was removed with a multiblade carbide bur in the present study, some residual material might be present. Therefore, the current findings suggest that this problem could be compensated by mechanical retention created by the recycling procedures.

Among the tested adhesives, Transbond XT presented significantly higher shear bond strength compared to the other adhesives at each bonding/debonding sequence, excep for Transbond XT versus Smartbond in new brackets, and Transbond XT versus Concise in brackets recycled twice. Higher shear bond strength for Transbond XT than for the other adhesives has already been observed[21,25].

In summary, aluminum oxide air-abrasion has been proved a good option for bracket recycling by offering a simple and easy-of-handle technique that can be performed in the dental office, which reduces the costs and working time. Therefore, recycled brackets can be of benefit to the profession, as long as the orthodontist is aware of the various aspects of the recycling methods, and that patients are informed about the type of bracket that will be used for their treatment.

Concluding, repeated bracket recycling using 50µm aluminum oxide particle air abrasion did not affect the shear bond strength of metallic brackets bonded with different orthodontic adhesives.

References

1. 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. 2001; 28: 231-6.
2. Maccoll GA, Rossouw PE, Titley KC, Yamin C. The relationship between bond strength and base surface area using conventional

and micro-etched foil-mesh bases. Am J Orthod Dentofacial Orthop. 1996; 109: 338-9.
3. Oliver RG, Pal AD. Distortion of edgewise orthodontic brackets associated with methods of debonding. Am J Orthod. 1989; 71: 65-71.
4. Hixson ME, Brantley WA, Pincsak JJ, Conover JP. Changes in brackets slot tolerance following recycling of direct-bond metallic orthodontic appliances. Am J Orthod. 1982; 81: 447-54.
5. Buchman DJL. Effects of recycling on metallic direct-bond orthodontics brackets. Am J Orthod. 1980; 77: 654-68.
6. Mascia VE, Chen SR. Shearing strengths of recycled directbonding brackets. Am J Orthod. 1982; 82: 211-6.
7. Buchwald A. A three-cycle in vivo evaluation of reconditioned direct-bonding brackets. Am J Orthod. 1989; 95: 352-4.
8. Millet D, Mccabe JF, Gordon PH. The role of sandblasting on the retention of metallic brackets applied with glass ionomer cement. Br J Orthod. 1993; 201: 117-22.
9. Senay C, Iiken K, Ela A. The effect of enamel air abrasion on the retention of bonded metallic orthodontic brackets. Am J Orthod Dentofacial Orthop. 2000; 117: 15-9.
10. Jassem HA, Retief DH, Jamison HC. Tensile and shear strengths of bonded and rebonded orthodontic attachments. Am J Orthod. 1981; 79: 661-8.
11. Mascia VE, Chen SR. Shearing strengths of recycled direct-bonding brackets. Am J Orthod. 1982; 82: 211-6.
12. Wright WL, Powers JM. In vitro tensile bond strength of reconditioned brackets. Am J Orthod. 1985; 87: 247-52.
13. Buchwald A. A three-cycle in vivo evaluateon of reconditioned direct-bonding brackets. Am J Orthod Dentofacial Orthop. 1989; 95: 352-4.
14. Regan D, van Noort R, O'Keeffe C. The effects of recycling on the tensile bond strength of new and clinically used stainless steel orthodontic brackets: an in vitro study. Br J Orthod. 1990; 17: 137-45.
15. Postlethwaite KM. Recycling bands and brackets. Br J Orthod. 1992; 19: 157-63.
16. Tavares SW, Consani S, Nouer DF, Magnani MB, Nouer PR, Martins LM. Shear bond strength of new and recycled brackets to enamel. Braz Dent J. 2006; 17: 44-8.
17. Tavares SW, Consani S, Nouer DF, Magnani MBBA, Pereira Neto JS, Romano FL. Evaluation in vitro of the shear bond strength of aluminum oxide recycled brackets. Braz J Oral Sci. 2003; 7: 378-81.
18. MacColl GA, Rossouw PE, Titley KC, Yamin C. The relationship between bond strength and orthodontic bracket base surface area with conventional and microetched foil-mesh bases. Am J Orthod Dentofacial Orthop. 1998; 113: 276-81.
19. Sonis AL. Air abrasion of bonded metal brackets: a study of shear bond strength and surface characteristics as determined by scanning electron microscopy. Am J Orthod Dentofacial Orthop. 1996; 110: 96-8.
20. Meehan MP, Foley TF, Mamandras AH. A comparison of the shear bond strengths of two glass ionomer cements. Am J Orthod Dentofacial Orthop. 1999; 115: 125-32.
21. Rix D, Foley TF, Mamandras A. Comparison of bond strength of three adhesives: composite resin, hybrid GIC, and glass-filled GIC. Am J Orthod Dentofacial Orthop. 2001; 119: 36-42.
22. Bishara SE, Ostby AW, Laffoon JF, Warren J. Shear bond strength comparison of two adhesive systems following thermocycling. A new self-etch primer and a resin-modified glass ionomer. Angle Orthod. 2007; 77: 337-41.
23. Toledano M, Osorio R, Osorio E, Romeo A, de la Higuera B, Garcia-Godoy F. Bond strength of orthodontic brackets using different light and self-curing cements. Angle Orthod. 2003; 73: 56-63.
24. 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 Dentofacial Orthop. 2002; 121: 521-5.
25. Romano FL, Tavares SW, Nouer DF, Consani S, Borges de Araujo Magnani MB. Shear bond strength of metallic orthodontic brackets bonded to enamel prepared with Self-Etching Primer. Angle Orthod. 2005; 75: 849-53.