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Shear Bond Strength of New and Recycled Brackets to Enamel

Stenyo Wanderley TAVARES[1]
Simonides CONSANI[2]
Darcy Flávio NOUER[1]
Maria Beatriz Borges de Araújo MAGNANI[1]
Paulo Roberto Aranha NOUER[3]
Laura Moura MARTINS[3]

[1]Discipline of Orthodontics;[2]Discipline of Dental Materials, Faculty of Dentistry of Piracicaba,
State University of Campinas (UNICAMP), Piracicaba, SP, Brazil
[3]Discipline of Orthodontics and Maxillary Functional Orthopedics,
São Leopoldo Mandic Research Center, Campinas, SP, Brazil

The purpose of this study was to evaluate *in vitro* the shear bond strength of recycled orthodontic brackets. S2C-03Z brackets (Dental Morelli, Brazil) were bonded to the buccal surfaces of 50 extracted human premolars using Concise Orthodontic chemically cured composite resin (3M, USA). The teeth were randomly assigned to 5 groups (n=10), as follows. In group I (control), the bonded brackets remained attached until shear testing (i.e., no debonding/rebonding). In groups II, III and IV, the bonded brackets were detached and rebonded after recycling by 90-µm particle aluminum oxide blasting, silicon carbide stone grinding or an industrial process at a specialized contractor company (Abzil-Lancer, Brazil), respectively. In group V, the bonded brackets were removed and new brackets were bonded to the enamel surface. Shear bond strength was tested in an Instron machine at a crosshead speed of 0.5 mm/min. Data were analyzed statistically by ANOVA and Tukey's test at 5% significance level. There was no statistically significant difference ($p>0.05$) between the control brackets (0.52 kgf/mm^2), brackets recycled by aluminum oxide blasting (0.34 kgf/mm^2) and new brackets attached to previously bonded teeth (0.43 kgf/mm^2). Brackets recycled by the specialized company (0.28 kgf/mm^2) and those recycled by silicon carbide stone grinding (0.14 kgf/mm^2) showed the lowest shear strength means and differed statistically from control brackets (0.52 kgf/mm^2) ($p<0.05$). In conclusion, the outcomes of this study showed that bracket recycling using 90-µm aluminum oxide particle air-abrasion was efficient and technically simple, and might provide cost reduction for orthodontists and patients alike.

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

INTRODUCTION

In Orthodontics, as well as in other dental fields, there is a trend to simplify the technical procedures to reduce operative time and treatment costs.

Before the 1970's, orthodontic treatment with fixed appliances was performed using stainless steel bands that were cemented to all teeth and then orthodontics brackets were welded to the bands. The technique of bonding orthodontic accessories directly to tooth surfaces has become possible after Buonocore's pioneer study (1), which proved the existence of a significantly stronger mechanical bond between restorative materials and dental enamel etched with 85% phosphoric acid for 30 s. The technique involving application of adhesive systems to acid-etched enamel allowed an optimal bonding of orthodontic brackets to tooth surface, which greatly improved and simplified the placement of fixed orthodontic appliances and widen the scopes and perspectives in Orthodontics (2).

It has been shown that, in spite of being transient, bonding between the bracket base and the enamel surface must be strong enough to withstand stresses and shear forces. Failure of the bonding technique, lack

Correspondence: Prof. Stenyo Wanderley Tavares, Av. 17 de Agosto, 1255/201, Casa Forte, 52060-590 Recife, PE, Brasil. Tel. +55-81-3268-1057. Fax: +55-81-322-1686. e-mail: stenyo@ig.com.br

of retention of the bracket base and masticatory forces also contribute for displacement of orthodontic accessories, which creates a common problem in orthodontic clinical practice that causes disturbance, delays the treatment and increases its costs.

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 (3). Although the clinical use may produce small distortions on the brackets, removal phase is responsible for most distortions and damages observed (4). Bracket recycling can be performed either in the dental office (immediate method) or by specialized companies without altering the slot positions (5).

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 (6-8). When the process involves chemical solvents, they are put in direct contact with the bonding agent at temperatures below 110°C followed by heat exposure at 250°C for sterilization. The companies that use such a method do not disclose solvent chemical composition. Heat itself is a crucial factor in the recycling process because of its negative influence on bracket microstructure. Most orthodontic brackets are made of austenitic stainless steel, which forms chrome-carbide compounds that precipitate at temperatures between 600^{o}C and 800^{o}C. This process leads to disintegration of the metal alloy and weakens its structure. In addition to chromium loss via carbide precipitation, corrosion strength also decreases (9). The recycling process is concluded by electrochemical polishing of the brackets to eliminate irregularities or excessive surface roughness and prevent the trend to opacity or corrosion resulting from the process.

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 to enhance the mechanical retention of new brackets and improve bracket bonding to restored teeth as well as to prepare the enamel surface (10,11).

The purpose of this study was to evaluate *in vitro* the shear bond strength of recycled brackets bonded to acid-etched enamel with chemically activated resin.

MATERIAL AND METHODS

The research proposal was first submitted to the local Ethics in Research Committee and the designed methodology was approved (protocol number: 63/2000).

Fifty healthy human premolars extracted for orthodontic reasons were collected from the Surgery Clinic of the Faculty of Dentistry of Piracicaba (UNICAMP), Brazil, rinsed in tap water, scrapped with a LeCron spatula (Dental Duflex, Rio de Janeiro, RJ, Brazil) to remove periodontal tissue remnants and stored in saline at 4^{o}C up to 6 months until use. All specimen preparation procedures were in compliance with ISO TR 11405 (Technical Report: Dental materials- Guidance on testing of adhesion to tooth structure) (12).

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.

Thereafter, a spot was chosen on the center of the buccal surfaces and the enamel site was etched with a 37% phosphoric acid gel (3M, St. Paul, MN, USA) for 30 s, followed by rinsing in tap water and air-drying for 20 s each. S2CO3Z brackets (Dental Morelli, Sorocaba, SP, Brazil) were bonded to the etched area with Concise Orthodontic chemically cured composite resin system (3M), after application of the adhesive system supplied by the manufacturer. A pair of a tweezers was used for holding the brackets. Five groups of 10 specimens each were formed. In group I (control), the bonded brackets remained attached to tooth surface until shear testing, i.e., no debonding/rebonding procedures were done. In groups II, III and IV, the bonded brackets were detached from the teeth and rebonded to the enamel surface after recycling by different techniques. Group II: 90-µm diameter particle aluminum oxide air-abrasion (Bio-Art, São Carlos, SP, Brazil) for 15 to 30 s (depending on the amount of residual bonding agent). A 10-mm distance was kept between the device tip and the bracket base (13). Group III: silicon carbide stone grinding (Pontas Schelble, Petrópolis, RJ, Brazil) at low speed. Group IV: cleaning by a specialized recycling contractor company (Abzil-Lancer, São José do Rio Preto, SP, Brazil) (unknown technique). In group V, the bonded brackets were detached from the teeth and new brackets were bonded to the enamel surface. Bracket removal from teeth in groups II, III, IV and V was performed with a pair of pliers (Starlet, São Paulo, SP, Brasil). Resin remnants were removed from tooth surface with multiblade carbide burs (9114F; KG Sorensen) at low speed, which were replaced by new ones every 5 teeth.

Rebonding of recycled brackets and attachment of new brackets (group V) were performed as described for the initial bonding procedures and the teeth were kept in 100% relative humidity at 37°C for 24 h. Shear bond strength was tested in a 4411 model Instron machine (Instron Corp., Canton, MA, USA) at a crosshead speed of 0.5 mm/min until rupture of the bracket-tooth union. Shear strength values were recorded in kgf/mm^2. The results were analyzed statistically by ANOVA and Tukey's test at 5% significance level.

The brackets were examined in an scanning electron microscope (LEO 435 VP; Leo Electron Microscopy Ltd., Cambridge, England) to observe the base meshes before (group I) and after debonding (groups II, III, IV and IV), as well as to asses the failure mode of debonded brackets.

RESULTS

Shear bond strengths (± SD) in kgf/mm^2 were the following : group I: 0.52 (± 0.23); group II: 0.34 (± 0.14); group III: 0.14 (± 0.07); group IV: 0.28 (± 0.14); group V: 0.43 (± 0.27).

Statistical analysis showed no significant difference ($p>0.05$) between groups I (control), II (air-abraded recycled brackets) and V (new brackets bonded to previously bonded teeth). Group IV (industrial recycling) did not differ statistically from groups II and V ($p>0.05$), but had statistically lower shear bond strength means than group I (control) ($p<0.05$). Group III (cleaning with a silicon carbide grinding stone) presented the lowest shear bond strength means and differed statistically from groups I, II and V ($p<0.05$).

DISCUSSION

Shear bond strength of new and recycled brackets has been a subject of great interest in orthodontic research. Several techniques have been used for recycling of orthodontic brackets, i.e., removal of resin remnants and reuse of debonded brackets, including air-abrasion, silicon carbide grinding and industrial processes. Recycling of debonded brackets aims to reduce the costs of replacing new orthodontic accessories.

Aluminum oxide air-abrasion has been proved a good option for bracket recycling by offering a simple, easy-of-handle technique. Sandblasting can be performed in the dental office, which reduces the costs and working time (13).

The results of this study showed no statistically significant difference among the control brackets, air-abraded recycled brackets and new brackets bonded to previously bonded teeth, which agrees with the findings of other authors (13). Another study using GAC brackets (9.9 mm^2) and light-cured resin showed no statistically significant difference between aluminum oxide air-abraded recycled brackets and new brackets regarding their retention (14). However, sandblasting efficiency also depends on bracket type (15).

Among the recycling techniques, aluminum oxide blasting provided the highest bond strengths. 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 micro-roughened surface on the bracket base, which increases the area available for composite bonding in comparison to the control brackets (14) (Figs. 1 and 2).

Group III differed statistically from groups I, II and V ($p<0.05$). Similar findings have been reported in other studies that showed lower bond strengths for brackets recycled by silicon carbide grinding in comparison to the newly bonded bracket (16-17). The differences in shear bond strength among these groups are probably due to abrasion of the retention mesh as well as the incomplete removal of composite resin. Under these conditions, if a new bonding resin layer is placed over an old bonding resin layer, and not in direct contact with the bracket mesh structure, loss of retention is expected (Fig. 3). As group III had the smallest shear bond strength of all groups, it may be assumed that this method is the least indicated for direct bracket recycling. The statistically similar results of groups III and IV are probably due to the lower quality and retentiveness of the microretentive surface created on bracket base mesh (Fig. 4), which might be the result of the type of polishing performed in these recycling processes.

The use of 50-µm aluminum oxide particle stream has been recommended for bracket recycling to increase retention by creating a roughened surface (18,19). In the present study, bracket blasting was done using the aluminum oxide particle size (90 µm) indicated in the instructions for use supplied by the manufacturer of the air-abrasion device. The same particle size used by other authors produced greater micro-roughness on bracket base surface, increasing considerably the area available for bracket attachment (14). Thus, by analogy, it was assumed that this technique would also increase the bonding of recycled brackets, which was confirmed by the results of air-abrasion (group II) compared to the other recycling techniques (groups III and IV).

It is likely that bracket recycling with 50-µm aluminum oxide particle air-abrasion (13) would provide better bracket surface polishing and lesser micro-roughness in comparison to the 90-µm size particle stream. However, it is likely that this less roughened surface would make brackets recycled using 50-µm aluminum oxide particles less retentive.

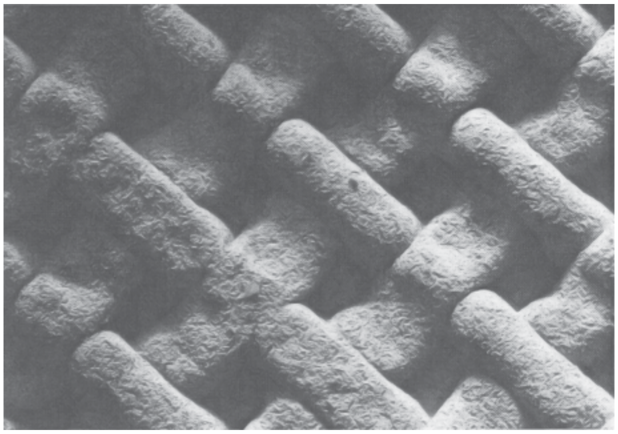

Figure 1. Group I (control) and Group V. Scanning electron micrograph showing the base of a new, non-reclyced bracket (original magnification X 200).

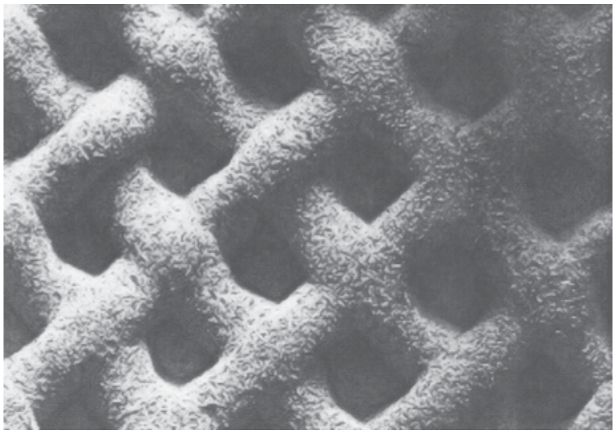

Figure 2. Group II. Scanning electron micrograph of a bracket base after recycling with aluminum oxide blasting (original magnification X 200).

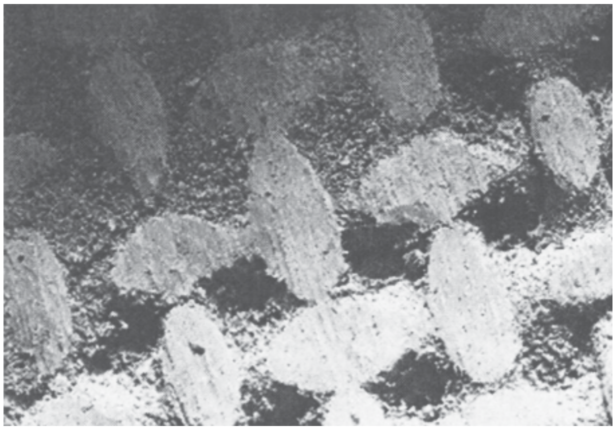

Figure 3. Group III. Scanning electron micrograph of a bracket base after recycling with silicon carbide grinding (original magnification X 200).

Figure 4. Group IV. Scanning electron micrograph of a bracket base after recycling by a specialized contractor company (original magnification X 200).

In this study, the time spent for bracket recycling with aluminum oxide air-abrasion was of 15 to 30 s on average. In general, the distance of 10 mm from the device tip to the bracket base caused no damage to the brackets (Fig. 2). Likewise, in a previous study, the same time and distance settings were used to remove resin residues without causing any damage to the bracket mesh (13). It has been shown that blasting of new brackets for 3 s before bonding to tooth surface produced good roughness without causing damages to the mesh (10). Failures most predominantly occurred at bracket-adhesive interface (90%), which is consistent with the findings of a previous investigation that reported 91.25% of failures at this interface.

The outcomes of this study demonstrated that bracket recycling using 90-µm aluminum oxide particle air-abrasion was efficient and technically simple, and might provide cost reduction for orthodontists and patients alike.

RESUMO

O objetivo deste estudo foi avaliar *in vitro* a resistência ao cisalhamento de bráquetes reciclados. Foram utilizados 50 pré-molares humanos, extraídos com finalidade ortodôntica, nos quais foi feita a colagem de bráquetes (S2C-03Z; Dental Morelli, Brasil) com resina composta quimicamente ativada (Concise Ortodôntico; 3M, EUA). Os dentes foram divididos aleatoriamente em 5 grupos (n=10). No grupo I (controle), os bráquetes colados permaneceram fixados até o momento do teste de cisalhamento (ou seja, não foram feitos procedimentos de remoção e nova colagem dos bráquetes). Nos grupos II, III e IV, os bráquetes foram removidos e reutilizados após reciclagem com jateamento de óxido de alumínio (90 µm), desgaste com ponta abrasiva de carboneto de silício ou processo industrial por uma empresa especializada (Abzil-Lancer, Brasil), respectivamente. No grupo V, os bráquetes foram removidos e bráquetes novos foram colados sobre o esmalte. Os ensaios de cisalhamento foram realizados numa máquina Instron com velocidade de 0,5 mm/min e os resultados foram submetidos à análise de variância e teste de Tukey com nível de significância de 5 %. Não houve diferença estatisticamente significante ($p>0,05$) entre os bráquetes do grupo controle (0,52 kgf/mm^2), reciclados com óxido de alumínio (0,34 kgf/mm^2) e bráquetes novos colados sobre o esmalte onde anteriormente havia bráquetes fixados (0,43 kgf/mm^2). Bráquetes reciclados pela empresa especializada (0,28 kgf/mm^2) e pelo desgaste com carboneto de silício (0,14 kgf/mm^2) apresentaram os menores valores de resistência ao cisalhamento, com diferença estatisticament significante ($p<0,05$) quando comparados aos bráquetes do grupo controle (0,52 kgf/mm^2). Deste modo, conclui-se que os resultados deste estudo mostraram que a reciclagem de bráquetes ortodônticos utilizando jateamento com de óxido de alumínio (90-µm) foi eficiente tecnicamente simples, podendo representar uma redução de custos para ortodontistas e pacientes.

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