RESEARCH ARTICLE

The Shear Strength of Orthodontic Attachments Made from Different Composites and Glued in Enamel Conditioned by Two Different Techniques

Matheus Soledade Carvalho Santos[1], Carolina Palmito Pereira[2], Alex Roney Costa Silva[3], Uillian Mozart Ferreira da Mata Cerqueira[4], Lucianne Cople Maia de Faria[5], Matheus Melo Pithon[6]

Received on: 12 May 2022; *Accepted on:* 05 July 2022; *Published on:* 17 February 2023

Abstract

Background: The use of removable thermoplastic appliances has become an alternative to the use of conventional fixed appliances through gradual, sequential, and consecutive dental repositioning. Aligners have become a reality.

Objective: To evaluate the shear strength of orthodontic attachments made from different composites and affixed to enamel treated with two different conditioning techniques.

Materials and methods: A total of 150 bovine incisors were randomly divided into 10 groups ($n = 15$). In groups I, III, V, VII, and IX, the tooth enamel was etched with 37% phosphoric acid, and then an adhesive was applied. In groups II, IV, VI, VIII, and X, enamel etching was performed with the self-etching agent Transbond Plus Self-Etching Primer (TPSEP). The composites used were Filtek Bulk Fill Flowable (groups I and II), Filtek One Bulk Fill (groups III and IV), Filtek Z350 XT (groups V and VI), Filtek Z250 XT (groups VII and VIII), and Filtek Z100 (groups IX and X). The attachments were molded in a silicone matrix adapted to the buccal area of the teeth, and then light-curing was performed. The samples were stored in distilled water for 24 hours. Subsequently, shear strength tests were performed using a universal mechanical testing machine. The results were analyzed using analysis of variance (ANOVA) and Kruskal–Wallis test and Student's *t*-test ($p = 0.05$).

Results: There were no significant differences ($p = 0.230$) among most of the adhesive systems for bonding orthodontic attachments. However, group VII differed from groups II, III, VI, and X ($p < 0.05$).

Conclusion: The Filtek Z250 XT composite on teeth etched with 37% phosphoric acid produced the strongest bond. The bonding was weakest with the Filtek One Bulk Fill composite on teeth etched with 37% phosphoric acid.

Clinical significance: With the popularization of aligners, it is necessary to test the materials involved in this treatment modality. Knowing the best material for making the attachments provides a more predictive treatment.

Keywords: Clear aligner, Orthodontics attachments, Shear strength.

International Journal of Experimental Dental Science (2021): 10.5005/jp-journals-10029-1233

Introduction

Patients and orthodontists look for both esthetics and comfort in orthodontic appliances.[1,2] With these considerations in mind, Align Technology (Santa Clara, CA, USA) introduced transparent alignment devices made of thermoplastic material in 1993 to treat malocclusions.[3]

The tooth movement caused by aligners is based on the schedule in each treatment step. It generates an intentional and pre-established "mismatch" between the material and the tooth. Inserted in the dental arch, the aligner corresponding to the new tooth position produces forces that are transmitted to the tooth, inducing a new tooth position.[4]

As aligner systems evolved, manufacturers incorporated attachments to improve tooth movement.[5] These accessories, made with composite resin, are placed on the surfaces of teeth to increase the retention of the aligner and provide support for rotational or translational dental movements.[6]

The bonding of orthodontic accessories using adhesives and composite resin has become the gold standard in orthodontic practice. Resin adhesives offer lower contamination risks and faster and more comfortable fixation of bondable oral accessories.[7,8]

To further reduce the patient's chair time as well as to avoid the uncontrolled demineralization of the enamel surface, SEP has been developed. The SEP is a system composed of a primer and a single acid solution; it eliminates one step in the fixation process.

[1–3,6]Department of Health I, State University of Southwestern Bahia, Jequié, Bahia, Brazil

[4]Federal University of Bahia, Instituto de Química, Campus da Federação/Ondina, Salvador, Bahia, Brazil

[5]Department of Pediatric Dentistry, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

Corresponding Author: Matheus Melo Pithon, Department of Health I, State University of Southwestern Bahia, Jequié, Bahia, Brazil, Phone: +557335289655. e-mail: matheuspithon@gmail.com

How to cite this article: Carvalho Santos MSC, Pereira CP, Silva ARC, *et al.* The Shear Strength of Orthodontic Attachments Made from Different Composites and Glued in Enamel Conditioned by Two Different Techniques. Int J Experiment Dent Sci 2021;10(2):58–62.

Source of support: Nil

Conflict of interest: Dr Matheus Melo Pithon is associated as the Editorial Board member of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of this editorial board member and his research group.

In addition to saving time, the simplicity of the bonding procedure can reduce the risk of procedural errors.[9]

However, there are no standards for choosing the most suitable materials and gluing techniques for making orthodontic attachments. This study evaluated different composites for making attachments and two techniques to condition enamel surfaces for bonding. In addition, it tested the hypothesis that there would be no difference in the strength of the bond between the attachment and the tooth when the attachments were made with different composites and the teeth were prepared with different enamel etching techniques.

Materials and Methods

Sample Selection

A total of 150 bovine permanent mandibular incisors were selected for this study. The teeth were soaked in a 10% formaldehyde solution for 7 days, followed by the removal of the periodontal ligament with a 15c scalpel (Solidor, Osasco, Brazil) and storage in a refrigerator at 5°C. For inclusion, teeth had to have a healthy enamel surface and no apparent defects. Those that presented anatomical variations, such as cracks that would complicate the adherence of the attachment to the enamel surface, were excluded.

Preparation of the Specimens

Using a self-curing acrylic resin (Classico, São Paulo, Brazil), the roots of each tooth were fixed in a reducing bushing that was 25 mm in diameter and 32 mm in height (Fortlev, São Paulo, Brazil). The crown was left exposed with the vestibular surface perpendicular to the ground.

Table 1: Conditioning techniques and composites

Group	*Conditioning*	*Material*	*Manufacturer*
I	37% phosphoric acid + adhesive	Filtek Bulk Fill Flowable (I)	3M
II	TPSEP	Filtek Bulk Fill Flowable (I)	
III	37% phosphoric acid + adhesive	Filtek One Bulk Fill (II)	
IV	TPSEP	Filtek One Bulk Fill (II)	
V	37% phosphoric acid + adhesive	Filtek Z350 XT (III)	
VI	TPSEP	Filtek Z350 XT (III)	
VII	37% phosphoric acid + adhesive	Filtek Z250 XT (IV)	
VIII	TPSEP	Filtek Z250 XT (IV)	
IX	37% phosphoric acid + adhesive	Filtek Z100 (V)	
X	TPSEP	Filtek Z100 (V)	

Compositions: (I) Ceramics treated with silane, urethane dimethacrylate (UDMA), ethoxylated bisphenol-A glycidyl methacrylate (bis-EMA), bisphenol-A glycidyl methacrylate (bis-GMA), benzotriazole, dimethacrylate replaced, dimetacrilato de trietilenoglicol (TEGDMA), and ytterbium fluoride
(II) Additional fragmentation monomer (AFM), aromatic urethane dimethacrylate (AUDMA), UDMA, and 1,12-dodecane-DMA
(III) Ceramics treated with silane, bis-GMA, bis-EMA, silica treated with silane, silica-zirconia oxide treated with silane, diurethane dimethacrylate, dimetacrilato polyethylene glycol TEGDMA, butylated hydroxytoluene (BHT), and pigments
(IV) Bis-GMA, UDMA, bis-EMA, and zirconia/silica
(V) TEGDMA, bis-GMA, and zirconia/silica

Distribution of Groups

The 150 incisors were randomly distributed into 10 groups ($n = 15$). A different combination of enamel conditioning technique and composite was tested in each group (Table 1).

Enamel Surface Preparation

Before the conditioning of the enamel surface, dental prophylaxis was performed with a mixture of pumice stone (Quimidrol, Joinville, Brazil) and water with a rubber cup (changed every five teeth) at low speed for 20 seconds. After prophylaxis, the teeth were washed and then dried for 20 seconds.

The enamel was conditioned following the manufacturer's recommendations. In groups I, III, V, VII, and IX, the enamel was etched with 37% phosphoric acid for 20 seconds, the surface was washed, and then the tooth was dried for 20 seconds. After that, an adhesive (Ambar, FGM, Joinville, Brazil) was applied with a microbrush and light-cured for 20 seconds.

In groups II, IV, VI, VIII, and X, the enamel surface was etched in a single step with a self-etching agent (SEP Transbond XT, 3M Unitek, Sumaré, Brazil). The components were mixed, rubbed on the enamel surface for 3 seconds, and then cured with a light air jet.

Preparation of the Attachments

Silicone matrices were used to prepare the attachments in a standardized fashion. The matrices were placed on the enamel surface and filled with the test composites. The composite in groups I and II, being a flow type, could be inserted directly. In the other groups, the composites were inserted using a composite insert spatula (Fig. 1).

Shear Strength Test

Resistance was tested using a universal test machine: AME-2 kN with a 500 kilogram-force (kgf) (Oswaldo Filizola, São Paulo, Brazil), set up following the ISO 29022 recommendations. A chisel-shaped tip was used and programmed to apply compression to the composite base at a speed of 1 mm/min.

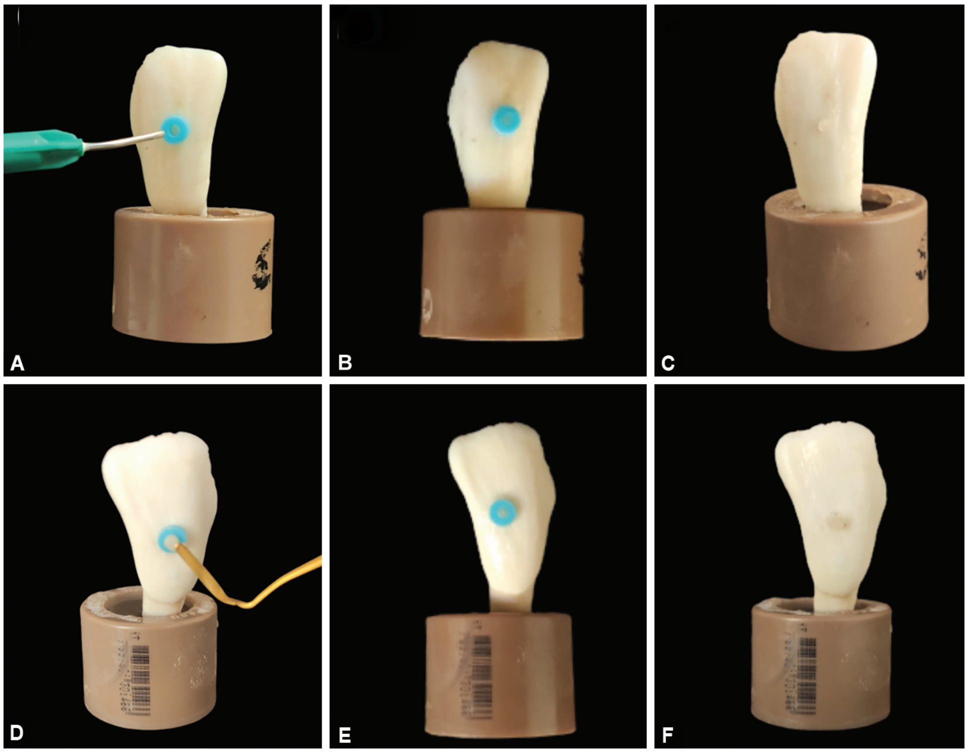
The specimens were placed on a flat surface so that the enamel surface was in a perpendicular position (Fig. 2). The shear force applied to the attachment/tooth enamel interface in the occluded-gingival direction was recorded by the machine in kgf. The values generated during the detachment were automatically transmitted to the computer at the moment of rupture by DynaView standard software.

Statistical Analysis

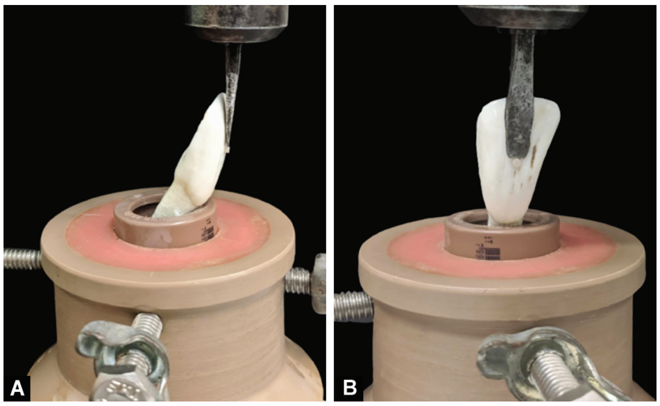
The statistical analysis was performed using jamovi, version 1.6.15. ANOVA was used to evaluate the results of the shear bond strength tests, and the Kruskal–Wallis H test was used for between-group comparisons. To evaluate the scores of the resins in pairs, the Student's t-test was used.

Results

The descriptive statistics for the shear strength values of the 10 groups are shown in Table 2. The highest mean for resistance was achieved in group VII (Filtek Z250 XT attachments bonded to teeth prepared with 37% phosphoric acid). The lowest mean was obtained in group III (Filtek One Bulk Fill attachments bonded to teeth prepared with 37% phosphoric acid).



Figs 1A to F: Preparing the attachments with composite resin: (A) Template filling with flow resin; (B) Template after removal of the excess resin; (C) Attachment after photo polymerization and removal of the template; (D) Inserting conventional resin by increments into the template; (E) Template after adaptation and removal of the excess resin; (F) Attachment after photoactivation and removal of the template



Figs 2A and B: Positioning the device for the shear strength test. (A) Side and (B) front

To evaluate the differences between groups, the shear resistance results were subjected to Kruskal–Wallis testing. There were no statistically significant between-group comparisons except for group VII (the Filtek Z250 XT attachments on teeth conditioned with 37% phosphoric acid) when compared to groups II, III, VI, and X, as shown in Table 3.

We also analyzed whether the type of conditioning agent would change the bonding of the composites as measured by the shear strength values. No significant differences ($p > 0.05$) were found between groups I and II (Filtek Bulk Fill Flowable), V and VI (Filtek Z350 XT), and IX and X (Filtek Z100). Groups III and IV (Filtek One Bulk Fill) and VII and VIII (Filtek Z250 XT) showed significant differences ($p < 0.05$). These findings are shown in Table 4.

Discussion

Attachments are accessories made with composites that are bonded to tooth surfaces as retentive elements. They improve the biomechanics of dental movement, allowing the construction of complex force systems.[3,4] In addition to having appropriate mechanical properties, attachments must resemble natural teeth in color, resist staining, and stand up to chewing.[10]

No previous studies have assessed the shear strength of orthodontic attachments. This is essential information as the failure of these accessories during treatment with aligners may increase the total treatment time. Therefore, this study evaluated the shear strength of dental composites commonly used in the manufacture of orthodontic attachments, testing the composites in association with two types of enamel conditioning.

The conditioning methods evaluated in this study were etching with 37% phosphoric acid, the gold standard for direct bonding to enamel, and the Transbond XT (3M) SEP, a single-step etching and adhesive system.[11] We chose to test the self-etching system because of the one-step process and the fact that it is hydrophilic, which gives it a good tolerance when glued in a humid environment. We evaluated two composites with a low shrinkage index, Filtek Bulk Fill Flowable and Filtek One Bulk Fill, and three conventional composites, Filtek Z350 XT, Filtek Z250 XT, and Filtek Z100. All of the materials were used as recommended by their manufacturers and subjected to the shear bond strength test.

When bonding was performed with the Filtek One Bulk Fill composite, shear strength was reduced when the tooth enamel was etched with 37% phosphoric acid. In contrast, conditioning with phosphoric acid provided superior strength when the bonding was performed with the Filtek Z250 XT composite. These results are of

Table 2: Descriptive shear strength (kgf) statistics

Groups	*N*	*Mean*	*SD*	*Minimum*	*Median*	*Maximum*	*Shapiro–Wilk*	*p-value**
I	15	2.83	1.22	1.63	2.32	5.62	0.009	0.230
II	15	2.10	1.19	0.928	1.69	5.71	0.002	
III	15	1.92	1.41	0.0510	2.07	4.58	0.533	
IV	15	3.78	1.60	1.03	3.84	7.30	0.879	
V	15	2.85	1.93	0.551	3.04	7.82	0.127	
VI	15	2.53	1.07	1.15	2.60	5.28	0.080	
VII	15	4.64	1.70	2.32	4.20	6.95	0.065	
VIII	15	2.94	0.688	1.80	2.97	4.36	0.989	
IX	15	3.10	1.90	0.632	2.56	6.44	0.141	
X	15	2.45	0.782	1.65	2.19	4.59	0.012	

*$p = 0.05$

Table 3: Comparison of values between adhesive system groups

Groups	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*
I	0.487	0.860	0.621	1.000	1.000	0.055	0.981	1.000	1.000
II		1.000	0.052	0.981	0.953	**0.003***	0.079	0.830	0.664
III			0.099	0.969	0.895	**0.011***	0.429	0.869	0.990
IV				0.869	0.443	0.969	0.807	0.953	0.167
V					1.000	0.361	1.000	1.000	1.000
VI						**0.022***	0.895	1.000	1.000
VII							0.143	0.286	**0.006***
VIII								1.000	0.532
IX									1.000

*$p = 0.05$; Bold numbers correspond to statistical significance

Table 4: Comparison of values between pairs of composites used on teeth that were conditioned differently

Adhesive system		*DF*	*p-value*
1	2	14.0	0.150
3	4	14.0	0.004
5	6	14.0	0.565
7	8	14.0	0.003
9	10	14.0	0.279

clinical importance. When deciding on the composite to use, great caution must be exercised in choosing the conditioning method.

It is well known that conventional resins require a meticulous operative technique. They require field drying, careful completion of several critical steps to condition the tooth enamel and dentin, and a maximum incremental thickness of 2 mm. These characteristics make the technique relatively more sensitive[12] and time-consuming.[13]

As a result, bulk fill composite resins were developed. These resins can be placed in increments of up to 4–6 mm, and exhibit low shrinkage stress and a high degree of polymerization at these depths due to the increase in the translucency structure and the presence of polymerization modulators.[14] They are simpler and faster to use in making attachments.

In the present study, the bonding strength was increased when conditioning was performed with self-etching primer (SEPT). But if the attachments were made with a flow composite (Filtek Bulk Fill Flowable) or the Filtek Z250 XT composite, the opposite situation was observed: the results were better when the teeth were conditioned with phosphoric acid. The Filtek Z250 XT group differed significantly from the Filtek Bulk Fill Flowable, Filtek Z350 XT, and Filtek Z100 groups bonded with the self-etching adhesive, and the Filtek One Bulk Fill group bonded using phosphoric acid and conventional adhesive.

There are a few recommendations in the literature for bonding protocols for orthodontic attachments made from composites. In contrast, many studies have compared the shear strength of metallic orthodontic brackets bonded with SEPT to those bonded using a conventional acid-etching system.[9,11,15,16] Additionally, Weckmann et al.[6] compared five different bonding protocols for attachments commonly used by professionals. They found that the choice of bonding protocol influenced the precision of the bond, and the use of a low viscosity composite or fixings made using a two-stage procedure with a high viscosity composite were most satisfactory.

Conclusion

The main hypothesis of this study was refuted. Although there were no statistical differences among the treatment combinations, differences in shear strength were observed in looking at the composites with each conditioning agent individually. The Filtek Z250 XT composite, on teeth conditioned with 37% phosphoric acid etching, had the highest shear strength, and the Filtek One Bulk Fill composite, under the same enamel etching conditions, had the lowest.

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