Effect of lingual enamel sandblasting with aluminum oxide of different particle sizes in combination with phosphoric acid etching on indirect bonding of lingual brackets

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ABSTRACT

Objective: To compare bond strength and bond failure location of lingual brackets indirectly bonded after lingual enamel sandblasting with 27-, 50-, and 90-μm aluminum oxide particles followed by 37% phosphoric acid etching.

Material and Methods: Eighty maxillary premolars were randomly divided into four equal groups according to the method of lingual enamel surface conditioning: Group 1 (control) was etched with 37% phosphoric acid, and group 2, group 3, and group 4 were sandblasted with 27-, 50-, and 90-μm aluminum oxide particles, respectively, prior to acid etching. Lingual brackets were indirectly bonded using the same protocol and adhesive (Sondhi) in all groups. The maximum shear bond strength required to debond the brackets was measured using a testing machine, and the bond failure location was classified according to the adhesive remnant index (ARI). Analysis of variance was used to compare the mean bond strength between groups. The differences between ARI scores were evaluated using the Kruskal-Wallis test.

Results: There were no statistically significant differences in mean shear bond strength or ARI scores between the four enamel-conditioning procedures.

Conclusion: Lingual enamel sandblasting using different particle sizes of aluminum oxide prior to phosphoric acid etching did not increase the shear bond strength of indirectly bonded brackets and did not affect the amount of adhesive remnant on the enamel. (*Angle Orthod.* 2014;84:1068–1073.)

KEY WORDS: Sandblasting; Lingual enamel; Lingual brackets; Acid etching

INTRODUCTION

In an effort to produce a more accurate and efficient bracket positioning system, Silverman et al.[1] developed the indirect bracket bonding technique. At first, the technique was deficient,[2] and many orthodontists abandoned the idea. However, in time, the indirect bonding has improved in technique,[3] materials,[4–6] and in vitro bond strength.[7,8] Clinical failure rates[9,10] are currently comparable with those found for directly bonded brackets.

Improvements of the indirect bonding technique have been particularly important for lingual orthodontics. The great anatomic variation of the lingual surfaces, the difficulty in access, the lack of direct visualization, and the need to customize the bracket bases to ensure adequate height, angulation, in/out, and torque often force orthodontists to bond lingual brackets using indirect bonding techniques.[11,12]

Bracket failure during orthodontic treatment poses a serious problem for orthodontists.[13] Some of the

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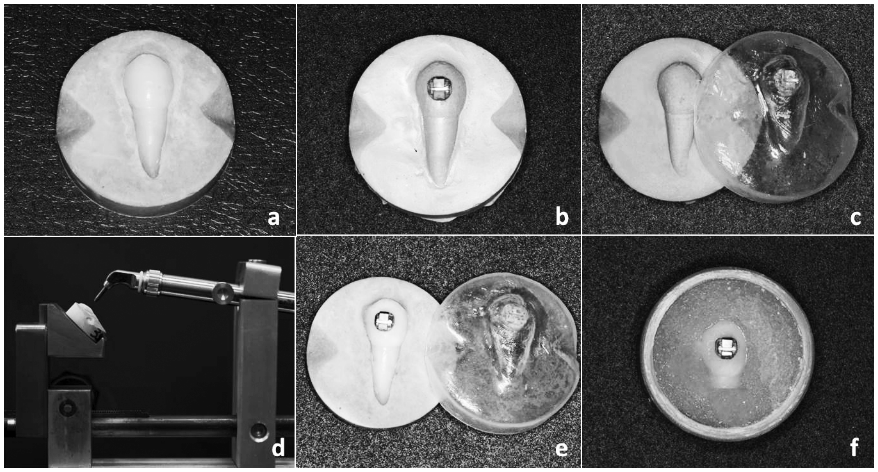

Figure 1. Specimen preparation. (a) Tooth embedded in dental plaster. (b) Bracket placement on the plaster model. (c) Bracket in transfer tray. (d) Specimen positioned on the device to be sandblasted. (e) Bonded bracket on tooth. (f) Tooth crown with the bonded bracket embedded in acrylic resin.

consequences are longer treatment time, additional material and personnel costs, and extra patient visits.[14] Differently from buccal orthodontics, in which direct rebonding is the preferred option, in lingual orthodontics rebonding sometimes should be indirect. As a complex stage that requires the manufacture of single-tooth transfer trays, indirect rebonding raises the risk of inaccurate repositioning and takes longer than direct rebonding.[11,15]

During indirect bonding, two surfaces are adhered: the enamel and the polymerized resin in the bracket base. Therefore, the conditioning of these surfaces is decisive in determining bond strength. Enamel conditioning is a fundamental stage of the bonding procedure because it produces micro grooves in the enamel surface, necessary for a good attachment of the bonding agent.[16] Currently, phosphoric acid etching is the conventional procedure.[16–20] However, to obtain better bond strengths and to preserve the integrity of enamel, other conditioning methods have been proposed, such as etching with different acids,[21] laser irradiation,[20,22] and aluminum oxide sandblasting.[16–20,23–27]

The use of aluminum oxide sandblasting combined with phosphoric acid etching or self-etching primers to increase the bond strength of orthodontic brackets remains controversial. Although some studies found an increase in bond strength,[15,18,23,26–28] others did not.[19,20,25,29–31] Moreover, the protocols used vary substantially in particle size, distance to the tooth surface, duration of the abrasion, and pressure of application.

The results of studies that evaluated the effect of aluminum oxide sandblasting combined with phosphoric acid etching on bond strength[15,18–20,26,27,29–31] have been diverse, and most studies have investigated this type of conditioning on the buccal surfaces. Still, some orthodontists use this technique to increase the bond strength on the lingual surfaces.[15,30,32] No previous study has evaluated the effect of aluminum oxide sandblasting using different particle sizes in combination with phosphoric acid etching during indirect bonding on lingual surfaces. Thus, this study compared bond strength and bond failure location of lingual brackets indirectly bonded after lingual enamel sandblasting with 27-, 50-, and 90-μm aluminum oxide particles in combination with phosphoric acid etching.

MATERIALS AND METHODS

Eighty maxillary premolars without caries, wear, fractures, or any other visible defects were stored in distilled water at room temperature until needed. The teeth were embedded separately in type IV dental plaster (Durone, Dentsply Ind and Com, Rio de Janeiro, Brazil) formed in an industrial silicone mold, so that the lingual surfaces remained above the plaster. Two V-shaped grooves were made on opposite sides of the upper edge of each specimen to ensure the correct positioning of the transfer trays in the test specimens at a later stage (Figure 1a).

Impressions of the teeth were taken using condensation silicone (Zetaplus, Zhermack SpA, Badia Polesine, Italy), and type IV dental plaster was poured. The plaster models were left to dry for 24 hours, after which a layer of an insulating agent diluted in water at a ratio of 1:1 was applied to the models, and 20 minutes were given for drying. The stainless-steel single-mesh base of the premolar lingual brackets (STB, Ormco Corporation, Orange, Calif) was cleaned with acetone to remove possible contamination due to handling. A small amount of Transbond XT adhesive (3M Unitek,

Table 1. Conditioning Protocols According to Groups

Groups	Enamel-Cleaning Procedure Before Conditioning	Conditioning Method
1 (Control)	Rubber cup and pumice, rinsing with water and drying with oil-free compressed air	Acid etching
2		27-μm sandblasting followed by acid etching
3		50-μm sandblasting followed by acid etching
4		90-μm sandblasting followed by acid etching

Monrovia, Calif) was applied to the metal mesh of brackets, which were then positioned at the center of the lingual surfaces. A load of 453.59 g was applied to the center of each bracket using a Gilmore needle to standardize the amount of resin, and any excess material was removed with a scaler (Figure 1b). The brackets were then light-cured for 10 seconds per side at a distance of 2 to 3 mm with an LED lamp and at a light intensity of 1100 mW/cm^2.

The transfer trays were made with 1-mm-thick flexible thermoplastic resin sheets (FGM Dental Products, Joinville, Brazil) in a vacuum-forming machine; they were then sectioned 3 mm below the upper edge of the models and submerged in water for 30 minutes. Later, transfer trays were carefully removed from models (Figure 1c), and the custom resin bases were photopolymerized again for 20 seconds. Immediately after, the custom bases were sandblasted with 50 μm aluminum oxide for 1 second and oil-free compressed air to remove possible residues of insulation agent, plaster, or any other contaminant.

The teeth were cleaned with a rubber cup and pumice, rinsed with water for 10 seconds, and dried with oil-free compressed air. After that, the specimens were randomly divided into 4 groups (n = 20), and a different enamel-conditioning protocol of the lingual surfaces was used for each group. In group 1 (control), 37% phosphoric acid (Email Preparator Blue, Ivoclar-Vivadent AG, Schaan, Liechtenstein) was applied for 30 seconds, after which the teeth were rinsed with water for 20 seconds and dried with oil-free compressed air until enamel acquired a white appearance. Specimens in groups 2, 3, and 4 were sandblasted using a Microetcher (Danville Engineering, Danville, Calif), with 27-, 50-, and 90-μm aluminum oxide particles at 70 psi for 3 seconds at a distance of 5 mm, perpendicular to the lingual surface of the tooth. Sandblasting was performed by positioning the specimens in a device that ensured standardized distance and application angle (Figure 1d). Then, 37% phosphoric acid was applied, as described for group 1 (Table 1).

After enamel conditioning, the brackets were indirectly bonded using the adhesive Sondhi Rapid Set (3M Unitek) according to the manufacturer's instructions. Transfer trays were positioned on the teeth, slightly pressed for 30 seconds, and removed after 2 minutes (Figure 1e).

Immediately after bonding, the teeth were placed in distilled water and stored for 24 hours at room temperature; thermocycling was then performed according to the following protocol: 500 cycles at 5°C and 55°C. The teeth were removed from the plaster cast to which they had been embedded, and their roots were sectioned using diamond discs. The crowns with the bonded brackets were embedded in plastic cylinders using acrylic resin (Figure 1f), so that the bracket bases were perpendicular to the cylinder walls. The specimens were stored for 48 hours in distilled water at room temperature before undergoing the shearing test.

A mechanical testing machine (Kratos, Industrial Equipment, Cotia, Brazil) with a load cell of 1 kN and crosshead speed of 0.5 mm/min was used to determine shear bond strength for bracket debonding. The specimens were placed so that the chisel was positioned at the tooth-bracket interface, allowing the force to be applied parallel to the bracket base. The force was recorded in Newtons (N) and divided by the area of the bracket base (8.34 mm^2) to obtain the value of shear bond strength in megapascals (MPa).

After bracket debonding, the lingual surfaces were examined using an optical stereomicroscope, and the adhesive remnant index (ARI) was calculated to evaluate bond failure interface. The ARI scores were: 0 = no adhesive on tooth surface, 1 = less than 50% adhesive remnant, 2 = more than 50% adhesive remnant, and 3 = 100% adhesive remnant.[21]

Statistical Analysis

Mean shear bond strength, standard deviations, and minimum and maximum values were calculated for each group. The normality of the bond strength data was evaluated with the Shapiro-Wilk test. One-way analysis of variance (ANOVA) was used to detect possible bond strength differences between groups, and the nonparametric Kruskal-Wallis test was used to detect differences in ARI scores. The level of significance was set at 5%.

RESULTS

The results of shear bond strength are shown in Table 2. There were no statistically significant differ-

Table 2. Mean Shear Bond Strengths and Standard Deviations by Group

Group	N	Mean* (n)	Mean (MPa)	SD (MPa)	Minimum (MPa)	Maximum (MPa)
1 (Control)	20	189.3	22.7	5.8	13.5	33.6
2 (27-μm sandblasting followed by acid etching)	20	208.6	25.0	4.6	17.1	30.5
3 (50-μm sandblasting followed by acid etching)	20	192.7	23.1	5.0	15.2	31.5
4 (90-μm sandblasting followed by acid etching)	20	185.5	22.2	5.9	13.4	32.6

* $P = .3843$.

ences in mean shear bond strength between the four groups ($P = .3843$).

Table 3 shows the ARI scores for each group. More than 50% of the specimens in groups 1, 2, and 3 had scores of 2 and 3, whereas in group 4, most specimens had a score of 1. However, there were no statistically significant differences in ARI scores between groups ($P = .6849$).

DISCUSSION

Several studies have evaluated enamel conditioning using aluminum oxide sandblasting in combination with phosphoric acid.[15,18–20,25–27,29–31] Some studies found an increase in bracket bond strength,[15,18,26,27] but others found no differences.[19,20,25,29–31] The buccal surface was used in most of these studies[15,18–20,25,27,30,31]; however, differences in bond strength between buccal and lingual surfaces[28,29] have been reported, and some clinicians recommend aluminum oxide sandblasting before acid etching[15,32] as part of the protocol of lingual bracket bonding. Therefore, the effect of lingual enamel sandblasting prior to acid etching should be further investigated to be clinically indicated in a more predictable way.

There is no consensus in the literature about what size of aluminum oxide particle should be used for enamel sandblasting.[5,18–20,23,25–27,29–31] The effect of aluminum oxide sandblasting with different particle sizes has been studied only when used in combination with a self-etching primer (SEP) and on the buccal surface[23]; however, no previous studies have evaluated aluminum oxide sandblasting using different particle sizes in combination with phosphoric acid etching for indirect lingual bracket bonding.

Mean shear bond strength values in the four groups evaluated in this study ranged from 22.2 to 25.0 MPa. These values are higher than those suggested as clinically appropriate by some authors[33,34] and those reported in studies[19,20,26,27,29,31] that evaluated the effect of aluminum oxide sandblasting in combination with phosphoric acid etching on bond strength of orthodontic brackets. In contrast, Wiechmann[15] found higher values, but his study used resin cylinders instead of brackets. The comparison between values obtained in our study and those reported in other investigations should be interpreted cautiously, because several factors may affect bond strength values, including the technique used to debond the brackets (shearing, traction, and torsion), crosshead speed, and the type of bracket.[35] Moreover, the tooth surface evaluated,[28,29] as well as differences in the aluminum oxide sandblasting protocol and in the materials used for bonding, may also affect results.[19]

The results of the ANOVA revealed that there were no significant differences in bond strength obtained at the conditioned lingual enamel when the conventional technique was used, with phosphoric acid, and when aluminum oxide sandblasting was used with different particle sizes in combination with acid etching. These results are in agreement with findings reported in other studies, which did not find any increase in bond strength of brackets bonded on lingual enamel conditioned with 50-μm aluminum oxide sandblasting in combination with acid etching[29] or SEP.[28] Nevertheless, Cal-Neto et al.[26] concluded that lingual enamel

Table 3. Scores for ARI by Group

	ARI Scores[a]			
	0	1	2	3
Group	% (n)	% (n)	% (n)	% (n)
1 (Control)	15 (3)	30 (6)	5 (1)	50 (10)
2 (27-μm sandblasting followed by acid etching)	0 (0)	35 (7)	25 (5)	40 (8)
3 (50-μm sandblasting followed by acid etching)	5 (1)	40 (8)	5 (1)	50 (10)
4 (90-μm sandblasting followed by acid etching)	0 (0)	55 (11)	20 (4)	25 (5)

[a] ARI indicates adhesive remnant index; 0, no adhesive is left on the tooth; 1, less than half of the adhesive is left on the tooth; 2, more than half of the adhesive is left on the tooth; and 3, all the adhesive is left on the tooth, with a clear impression of the bracket's mesh. $P = .6849$.

sandblasting using 50-μm aluminum oxide particles prior to phosphoric acid etching increases the shear bond strength of lingual brackets indirectly bonded in vitro, although the clinical performance was not significantly different. This discrepancy with respect to our results may be explained by the fact that Cal-Neto et al. used different lingual brackets and adhesives from the ones used in our study.

Our results also showed no significant differences in shear bond strength among the groups that were sandblasted with 27-, 50-, or 90-μm particles. This finding varies from that of Halpern and Rouleau,[23] who used 25-, 50-, and 100-μm aluminum oxide particles followed by the Transbond Plus SEP on the buccal surfaces of premolars and found an increase in the shear bond strength of orthodontic brackets proportional to particle size; nevertheless, there were no significant bond strength differences between groups when using 25-μm particles for sandblasting in combination with SEP or only SEP (control group).

The analysis of the tooth surface after bracket debonding revealed that there were different amounts of adhesive remnants. In groups 1, 2, and 3, more than 50% of the specimens had an ARI of 2 and 3, which indicates that most bonding failures occurred at the bracket-adhesive interface. In group 4, more than 50% of the specimens had an ARI of 1, which is indicative of failure at the enamel-adhesive interface. Reisner et al.[25] and Türköz et al.[20] also found that bonding failures in the groups that received acid etching and sandblasting with 50-μm aluminum oxide in combination with acid etching occurred primarily at the bracket-adhesive interface. In contrast, the results reported by Cal-Neto et al.[26] showed that most specimens in both study groups (phosphoric acid and sandblasting in combination with acid) had an ARI of 0, which indicates that failures occurred primarily between enamel and adhesive.

The Kruskal-Wallis test was used to evaluate whether the differences observed in the bond failure location between groups were statistically significant. Thus, the differences in ARI scores for the four types of enamel conditioning under study were not statistically significant. Brosh et al.[29] also did not find any differences in ARI scores between conventional etching and 50-μm aluminum oxide sandblasting in combination with acid etching on lingual surfaces, whereas other authors found significant differences in the amount of adhesive remnant on enamel on the buccal[20,31] and lingual[26,28] surfaces when brackets were bonded to enamel after acid etching or 50-μm aluminum oxide sandblasting combined with acid etching or SEP. These divergent findings may be associated with differences in sandblasting conditioning protocols, bonding materials, brackets, and bonding techniques.

The results suggest that aluminum oxide sandblasting prior to acid etching with the sandblasting protocol used in this study, regardless of particle size is an unnecessary step in indirect lingual bracket bonding when the purpose is to increase bond strength. However, this was an in vitro study, so caution should be taken in the extrapolation of its results to clinical situations. Enamel sandblasting is a complex procedure that should take several factors into consideration: particle size, abrasion agent hardness, water usage,[26] distance to the tooth surface, duration of the abrasion, pressure,[16] and angle of application. Therefore, further studies should investigate whether different abrasion protocols may affect bond strength and bond failure interface.

CONCLUSIONS

- Lingual enamel sandblasting using different aluminum oxide particle sizes prior to acid etching:
  1. Produced clinically acceptable values of in vitro shear bond strength.
  2. Did not significantly increase the shear bond strength or the amount of adhesive remnant on the enamel surface after debonding of indirectly bonded lingual brackets.

- There were no significant differences in shear bond strength or ARI scores among conditioning protocols with different aluminum oxide particle sizes.

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