Original Article

Influence of a Nonrinse Conditioner on the Bond Strength of Brackets Bonded with a Resin Adhesive System

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Abstract: The objective of this study was to compare the effect of a nonrinse conditioner (NRC) and the conventional acid-etch technique on the shear bond strength and the adhesive remnant on the tooth after debonding brackets bonded with the resin orthodontic adhesive system Transbond XT. A total of 40 human premolars were divided into group I, phosphoric Acid/Transbond XT (n = 25) and group II, NRC/Transbond XT (n = 15). Shear bond strength was measured with a universal test machine with a crosshead speed of 1 mm/min. The adhesive remnant was quantified using image analysis equipment. Scanning electron microscope (SEM) observations were also carried out to observe enamel surfaces treated with each product. No significant differences were observed in the bond strengths of the two groups evaluated. The amount of adhesive remnant on the tooth after debonding was significantly less when conditioning the enamel with NRC compared with phosphoric acid. SEM observations showed that the NRC produced a more conservative etch pattern than phosphoric acid. (*Angle Orthod* 2005;75:400–405.)

Key Words: Nonrinse conditioner; Shear bond strength; Orthodontic adhesives

INTRODUCTION

The enamel etching technique was initially based on the use of phosphoric acid[1] and, during the years, the use of other acids such as maleic acid,[2,3] nitric acid,[4] ethylenediaminetetraacetic acid,[5] have been studied. Nevertheless, phosphoric acid has remained the principal enamel etchant since it was first introduced by Buonocore.[1]

Although most professionals accept acid etching as a routine technique, the literature on this matter agrees that acid etching produces iatrogenic effects on the enamel surface, amongst them, the loss of enamel.[6–9] Numerous investigations have reported on the effects of acid concentration and etching time on the loss of enamel and bond strength.

The most consistently uniform and adequate enamel etch pattern is obtained with 30–40% phosphoric acid concentrations.[9–12] Some studies evaluated the bond strength of brackets using acid concentrations lower than 37%, the standard concentration used. Wang et al[13] used 10–30% acid concentrations and obtained clinically adequate bond strengths with minimal enamel loss. However, when they used 5% concentrations, they observed a significant reduction of bond strength.

The standard etching technique for the direct adhesion of brackets has been etching with phosphoric acid for 60 seconds. However, different authors have indicated that the traditional 37% phosphoric acid etching for 60 seconds could be reduced to 15 seconds without observing significant differences in bond strength.[13–15]

In an attempt to improve the adhesion procedures, reduce the loss of enamel, and save chair time, a nonrinse conditioner (NRC, Dentsply DeTrey, Konstanz, Germany) has been introduced in the market. NRC conditions the dental structure without the need for rinsing after its application. The manufacturer recommends its use for the adhesion of compomers.

Cehreli and Altay[5] observed that the application of NRC produced a smooth yet ''adequately rough'' enamel surface for bonding. However, Bishara et al[12] obtained significantly lower bond strengths when combining a NRC with a compomer than when etching the enamel with phosphoric acid and a conventional resin orthodontic adhesive.

To our knowledge, there are no studies that have evaluated the use of NRC with resin orthodontic adhesive systems. The objective of this study was to evaluate the effect of NRC on the shear bond strength and the adhesive remnant on the tooth after debonding brackets that had been bonded with the orthodontic adhesive system Transbond XT (3M Unitek Dental Products, Monrovia, Calif) and to

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compare these results with the results using the conventional acid-etch technique. Scanning electron microscope (SEM) observations were also carried out to observe enamel surfaces treated with each product.

MATERIALS AND METHODS

Teeth

A total of 52 human maxillary premolars, free from caries and fillings were used. These teeth had been extracted for reasons unrelated to the objectives of this study and with the informed consent of the patients. The project was approved by the Murcia University Bio-ethical Commission.

The teeth were washed in water to remove any traces of blood and then placed in a 0.1% thymol solution. Afterward, they were stored in distilled water that was changed periodically to avoid deterioration. In no case was a tooth stored for more than a month after extraction.

For the shear bond strength test, 40 premolars were set with their roots in type-IV plaster in a 4-cm-long copper cylinder with an internal diameter of 3 cm. For SEM observations, 12 premolars were used.

Brackets

Forty metal maxillary premolar brackets were used (Victory Series, 3M Unitek Dental Products). The base area of each bracket was calculated (mean = 9.79 mm^2) using image analysis equipment and MIP 4 software (Micron Image Processing Software, Digital Image Systems, Barcelona, Spain).

Bonding procedure

The maxillary premolar teeth were divided into two groups and brackets were bonded on the buccal surfaces according to the instructions supplied by the manufacturer of each product. For all groups, the buccal surfaces were polished with a rubber cup and polishing paste (Détartrine, Septodont. Saint-Maur, France).

Group I (n = 25): phosphoric acid/Transbond XT. The area where the bracket was to be located was etched with a 37% *o*-phosphoric acid gel (Total Etch, Ivoclar, Vivadent, Schaan, Liechtenstein) for 30 seconds and then washed with water. After washing, the enamel surface was completely dried with compressed air. A layer of Transbond XT primer was applied on the tooth. Transbond XT paste was applied to the base of the bracket and pressed firmly onto the tooth. Excess adhesive was removed from around the base of the bracket, and the adhesive was light cured positioning the light guide of an Ortholux XT lamp (3M Unitek Dental Products) on each interproximal side for 10 seconds.

Group II (n = 15): NRC/Transbond XT. NRC was brushed gently onto the enamel leaving it undisturbed for 20 seconds. Then a moisture-free air source was used to deliver a gentle burst of air to the enamel. Afterward, the bracket was bonded with Transbond XT (primer and paste) as in group I.

Storage of test specimens

The specimens were immersed for 24 hours in distilled water at a temperature of 37°C.[16]

Bond strength test

Shear bond strength was measured with a universal test machine (Autograph AGS-1KND, Shimadzu, Kyoto, Japan) with a one kN load cell connected to a metal rod with one end angled at 30°. The crosshead speed was 1 mm/min.[16]

The teeth were set at the base of the machine so that the sharp end of the rod incised in the area between the base and the wings of the bracket, exerting a force parallel to the tooth surface in an occlusal-apical direction.

The force required to debond each bracket was registered in newtons, and converted into megapascals as a ratio of newtons to surface area of the bracket (MPa = N/mm^2). To compare different bond test studies correctly, it is necessary to determine bond strength. The use of the force of debonding only does not permit comparisons of brackets with different geometries.

Adhesive remnant index

The percentage of the surface of the bracket base covered by adhesive was determined using an image analysis equipment (Sony dxc 151-ap video camera, connected to an Olympus SZ11 microscope) and MIP software.

The percentage of the area still occupied by adhesive remaining on the tooth after debonding was obtained by subtracting the area of adhesive covering the bracket base from 100%. Afterward, each tooth was assigned an adhesive remnant index (ARI) value according to the following criteria:[17] 0 = no adhesive left on the tooth; 1 = less than half of the adhesive left on the tooth; 2 = more than half of the adhesive left on the tooth; 3 = all adhesive left on the tooth.

Possible macroscopic enamel fractures were also registered.

Statistical analysis

The Kolmogorov-Smirnov normality test and the Levene variance homogeneity test were applied to the bond strength data. Because the data did not show a normal distribution, a significant difference was evaluated ($P < .05$) using the Mann-Whitney test for two independent samples.

ARI values were analyzed using the Pearson chi-square test and an analysis of corrected residues. A significance level $P < .05$ was set for both Pearson chi-square test and

TABLE 1. Shear Bond Strength (in MPa)[a]

Group	n	Mean	Median	Standard Deviation	Minimum	Maximum
Phosphoric acid	25	12.27	11.30	5.01	6.79	28.01
NRC[b]	15	10.45	12.05	4.09	4.65	15.60

[a] The Mann-Whitney *U*-test did not detect significant differences. $P < .05$.

[b] NRC indicates non-rinse conditioner.

the analysis of corrected residues (residue >2 implies $P < .05$).

The Kolmogorov-Smirnov test and the Levene homogeneity test of variances were applied to the data for percentage of area of adhesive remaining on tooth. Because the data showed a normal distribution and there was homogeneity of variances in the groups, they were analyzed using the *t*-test for two independent samples ($P < .05$).

Field emission SEM observation

SEM was used to observe the effect of conditioning with phosphoric acid and the NRC on buccal enamel surface. Twelve bicuspids were divided into four groups. The crowns were sectioned from the roots with a diamond disc at the labial cementoenamel junction and each crown was cut longitudinally in a mesiodistal direction: (1) the enamel was polished with a rubber cup and polishing paste; (2) the enamel was polished with a rubber cup and polishing paste and etched with a 37% *o*-phosphoric acid gel for 30 seconds. Then the enamel was rinsed with water and air dried; (3) the enamel was polished with a rubber cup and polishing paste, and NRC was gently brushed onto the enamel leaving it undisturbed for 20 seconds. A moisture-free air source was used to deliver a gentle burst of air to the enamel.

All specimens were cleaned in distilled water with ultrasonic agitation for 30 minutes and gently air dried. Then, they were affixed to SEM stubs, sputter coated with gold, and examined on a Jeol 6100 SEM operating at 15 kV. Representative images for the different surface treatments were captured digitally and stored in computer files.

RESULTS

The results for bond strength are shown in Table 1. The Mann-Whitney test for two independent samples did not show significant differences ($P = .44$) between the groups evaluated (Table 1).

The Pearson chi-square test observed significant differences ($P = .00$) in the ARI. The analysis of corrected residuals showed that whereas the acid-etched group was significantly associated (residue = 4) with two points on the ARI, NRC was associated with one index point (residue = 4) (Table 2).

The results for the percentage of area of tooth occupied by adhesive are shown in Table 3. The *t*-test for two independent groups detected significant differences between the groups ($P = .00$) (Table 3).

TABLE 2. Adhesive Remnant Index (ARI)[a]

		ARI			
Group	n	0	1	2	3
Phosphoric acid	25	0	7	18[b]	0
NRC[c]	15	0	14[b]	1	0

[a] ARI values were analyzed by means of the Pearson chi-squared test (obtaining significant differences) and an analysis of corrected residuals. $P < .05$.

[b] Indicates the ARI value to which each group is associated significantly according to the residuals analysis, $P < .05$.

[c] NRC indicates non-rinse conditioner.

TABLE 3. Percentage of Tooth Area Occupied by Adhesive[a]

Group	n	Mean	Median	Standard Deviation	Minimum	Maximum
Phosphoric acid	25	59.88	60.82	19.20	17	89
NRC[b]	15	15.90	11.42	14.00	3	56

[a] The *t*-test for two independent samples detected significant differences between the groups. $P < .05$.

[b] NRC indicates non-rinse conditioner.

Figures 1 through 3 show the SEM observations. The enamel surface polished with a rubber cup and polishing paste appeared very smooth (Figure 1). Treatment with NRC resulted in a fine surface roughening and also pitted enamel surfaces (Figure 2). The enamel treated with phosphoric acid showed a rougher surface and an overall increase in microporosity (Figure 3).

DISCUSSION

This study evaluated the use of NRC with the resin orthodontic adhesive system Transbond XT.

Our results showed no significant differences between the bond strength of the group in which the enamel was treated with NRC and the group in which the acid-etch technique was used.

The values of the percentage of tooth area occupied by adhesive and the ARI indicated that NRC left less adhesive on the enamel surface than when the enamel was etched with 37% phosphoric acid. This fact is advantageous for professionals when removing the adhesive after debonding brackets.

SEM observations showed that the NRC produced a more conservative etch pattern than phosphoric acid and that the NRC was also potentially adequate for orthodontic adhesion needs. These results concur with other studies,[5,18] which also observed a more aggressive etch pattern using phosphoric acid than that produced by conditioning the enamel with NRC.

The fact that the use of NRC minimizes the loss of enamel is of great interest. Fluoride is not equally distributed

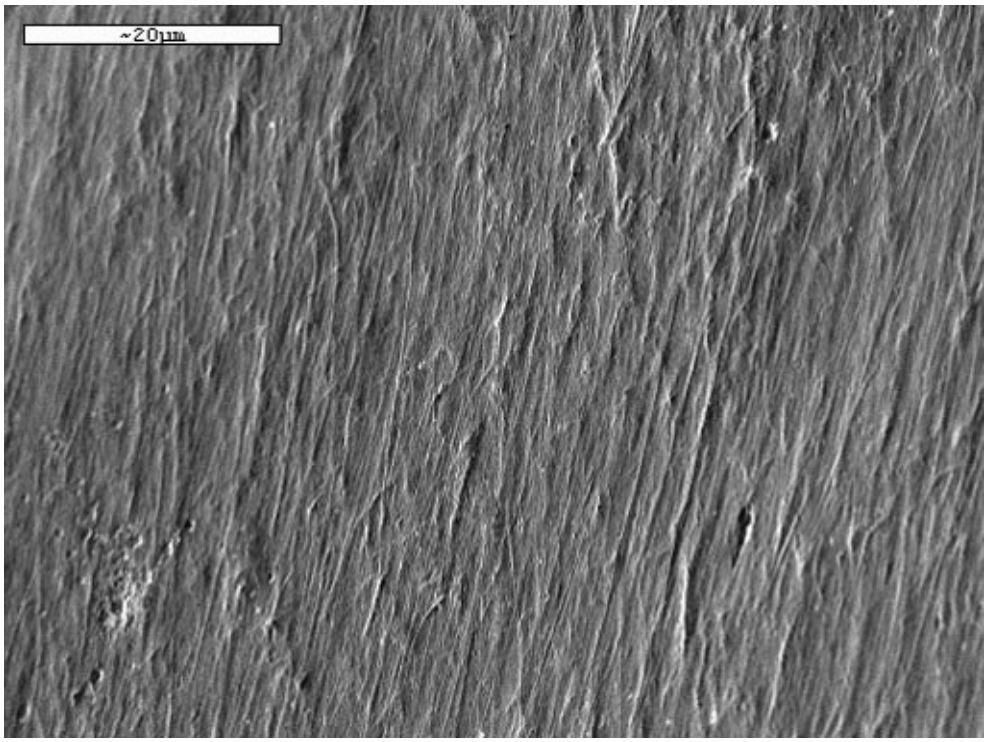

FIGURE 1. Scanning electron microscope view of the intact enamel polished with a rubber cup and polishing paste.

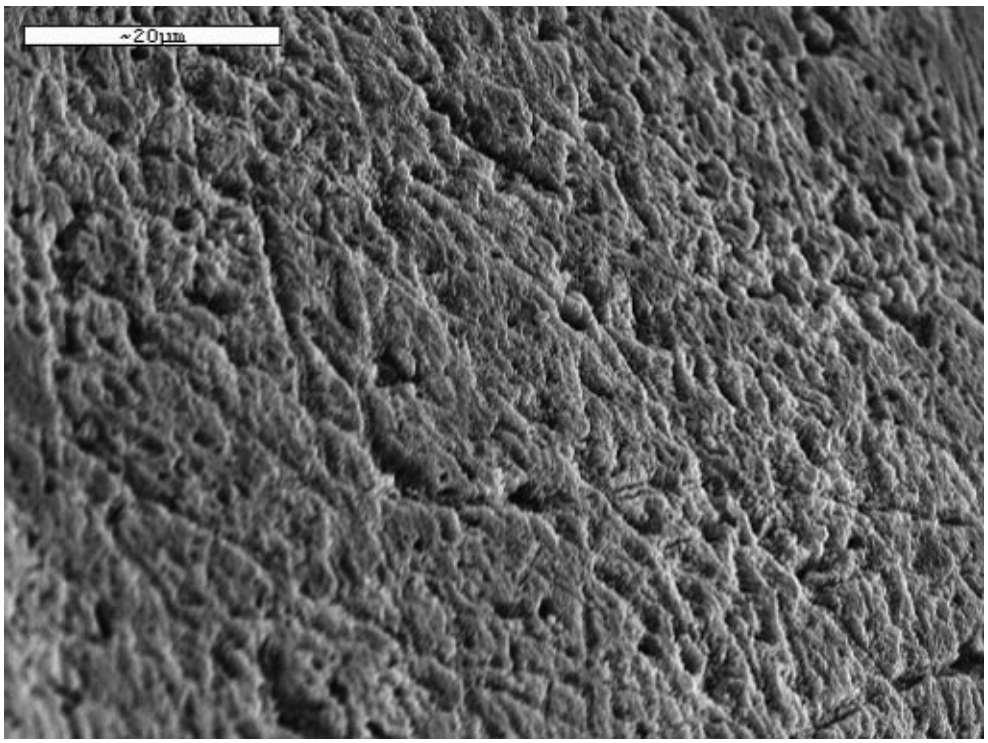

FIGURE 2. Scanning electron microscope micrograph of enamel after application of nonrinse conditioner.

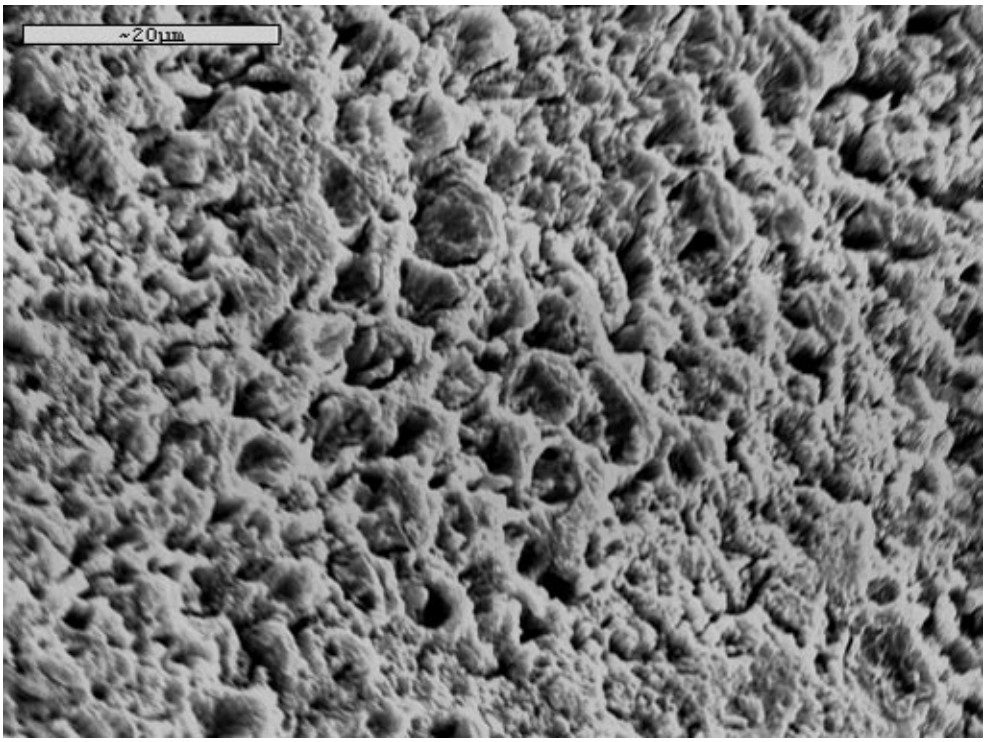

FIGURE 3. Scanning electron microscope view of enamel after etching with 37% phosphoric acid for 30 seconds.

over the enamel; it has a negative exponential distribution with greater concentrations in the surface. The permanent loss of enamel surface rich in fluoride during the etching process, before the orthodontic bonding, can make enamel surfaces more sensitive to decalcification. Many researchers have observed that, during orthodontic treatment, the enamel that is adjacent or subjacent to the brackets frequently shows decalcification.[19]

It is also useful to note that the use of NRC that etches the enamel without needing to be rinsed reduces the number of clinical procedures. Furthermore, because the rinsing step is eliminated, the risk of salivary contamination during the changing of cotton swabs after rinsing is also eliminated.[5]

CONCLUSIONS

- No significant differences were found in the bond strength of brackets bonded with Transbond XT when the enamel was conditioned with NRC and when the acid-etch technique was used.
- The amount of adhesive on the enamel after debonding was significantly less when using NRC than using phosphoric acid.
- SEM observations showed that NRC produced a more conservative etch pattern than phosphoric acid.

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