

Bracket bonding with 15- or 60-second etching and adhesive remaining on enamel after debonding

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Abstract: The purposes of this study were to (1) evaluate the shear bond strength of brackets fixed to enamel that has been etched for 15 or 60 seconds, (2) correlate etch time with amount of resin remaining on the enamel after debonding; and (3) evaluate enamel morphology after acid etching. Sixty recently extracted human premolars were randomly divided into two groups. Group 1 was etched for 15 seconds, and group 2 for 60 seconds. A 37% phosphoric acid solution was used for etching. The brackets were Mini-Taurus, and the bonding system was Mono-Lok2. After bonding, the teeth were held at 37°C and 100% humidity for at least 48 hours. To debond, a blade was placed at the ligature groove of the bracket. The force in Newtons required to dislodge the bracket was measured, employing a crosshead speed of 1 mm/min. Bond strength was calculated on the basis of bracket area. Immediately after removal of the bracket, the teeth were rinsed and dried using an air-water syringe, and the adhesive remnant index (ARI) was assessed. Enamel surfaces were analyzed using a scanning electron microscope (SEM). The results showed that shear bond strength was greater ($p=0.016$) when the enamel was etched for 60 seconds, and the amount of adhesive remaining on the teeth was also greater ($p=0.001$). There was no significant correlation between shear bond strength and the ARI calculated in the total sample ($n=60$, $r=0.017$; $p>0.05$). SEM evaluation revealed that the shorter etching time created a less retentive enamel surface. Absolute enamel loss also decreased.

Key words: Brackets, Bond strength, Enamel etching, Debonding

Direct bonding of orthodontic brackets to etched enamel is widely used by orthodontists and pediatric dentists.

The time required for proper bonding of orthodontic brackets has been investigated by several authors. These studies have included morphological observations of the enamel surfaces after different etching times,¹⁻³ determination of the bracket bond strengths using different etching times and bonding resins,⁴⁻⁸ effect of enamel etching time on bond strength and enamel surface morphology,⁹ effect of reduced acid concentration and etching time on enamel surface morphology and bond strength,¹⁰ and clinical performance of reduced etching time and acid concentration.¹¹

Successful clinical bonding may be obtained by a shear bond strength of 6 to 8 MPa.¹² In order to speed bracket placement, enamel etching with 37% phosphoric acid has been reduced from 60 seconds to 15 seconds, with little effect on bracket bond strength.¹³ Even when a 2% phosphoric acid concentration ap-

plied for 30 seconds was used, clinically reliable bonding was achieved.¹¹

Immediately after completion of orthodontic treatment, brackets are removed and remaining resin is eliminated to avoid plaque accumulation and for esthetic reasons. However, removing the adhesive can leave the enamel surface rough. Ideally, a clinical bonding method that leaves the least amount of resin on the tooth surfaces should be employed.

The purposes of this study were (1) to evaluate the shear bond strength of brackets fixed to enamel that has

been etched for 15 or 60 seconds, (2) to correlate etch time with the amount of resin remaining on the enamel after bracket debonding, (3) to evaluate the enamel morphology after acid etching.

Materials and methods

Shear bond strength

Sixty recently extracted human premolars were stored in distilled water at room temperature to prevent dehydration. All teeth were free of large restorations or carious lesions that might affect enamel strength.

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The twin bracket Mini-Taurus (Rocky Mountain Orthodontics Inc, Denver, Colo) was used for this study. The bracket base area was 9 mm². The Mono-Lok2™ self-curing bonding system (Rocky Mountain Orthodontics Inc, Denver, Colo) was used. It consists of a liquid and a highly filled composite resin paste. The filler in the adhesive consists of inorganic microparticles. The 60 premolars were randomly divided into two sets of 30 teeth to be treated with a phosphoric acid solution for either 15 or 60 seconds.

The bonding sites on each tooth were then cleaned with pumice-water paste using a rubber cup mounted on a low-speed contra-angle hand-piece for 15 seconds. The surface was rinsed with water and dried with air. Thirty teeth were treated with a 37% phosphoric acid solution in liquid form for 60 seconds and the other 30 teeth were treated for 15 seconds, followed by a 20-second rinse. The teeth were then dried with moisture-free, compressed air and bonded with adhesive according to manufacturer's instructions. First, the liquid was applied to the etched enamel surface and the bracket base with a brush. The paste was then applied to the bracket base and the bracket was firmly pushed onto the prepared surface of the tooth with a bracket holder. Excess adhesive was carefully removed with a hand scaler before polymerization. After an initial polymerization of 15 minutes, all the teeth were stored in 100% humidity at 37°C for at least 48 hours before debonding to ensure polymerization of the resin.

An Electrottest 500 testing machine (Ibertest, Madrid, Spain) was used to test the debonding strength. A special holder was constructed to provide a grip. A shearing blade was used to apply a force at the ligature groove of the bracket. The force in Newtons (N) required to dislodge the bracket was measured employing a crosshead speed of 1 mm/min. Bond

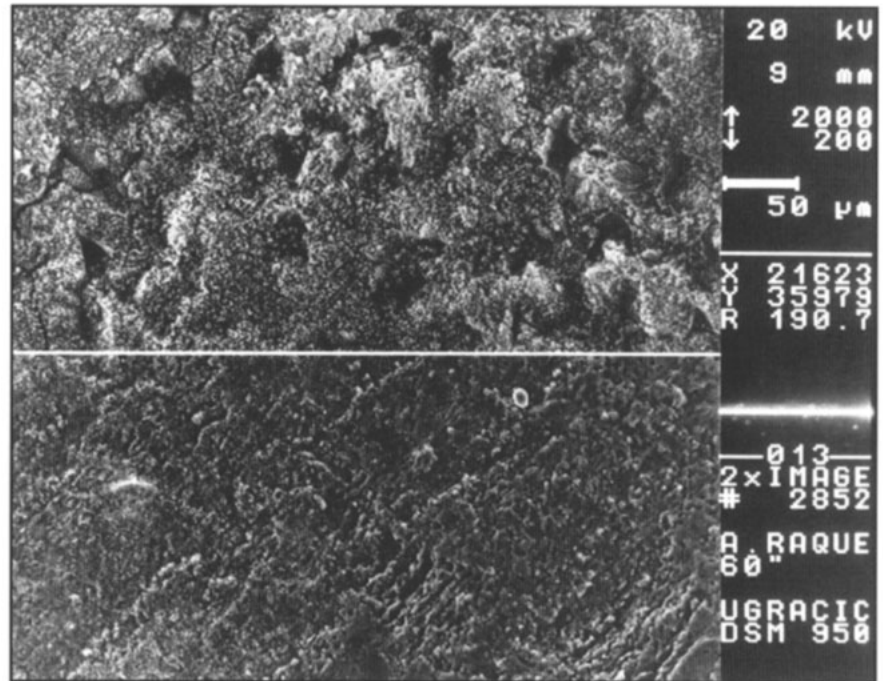


Figure 1

SEM micrograph of the enamel surface treated with a 37% phosphoric acid solution for 60 seconds (original magnification, top x2000, bottom x200).

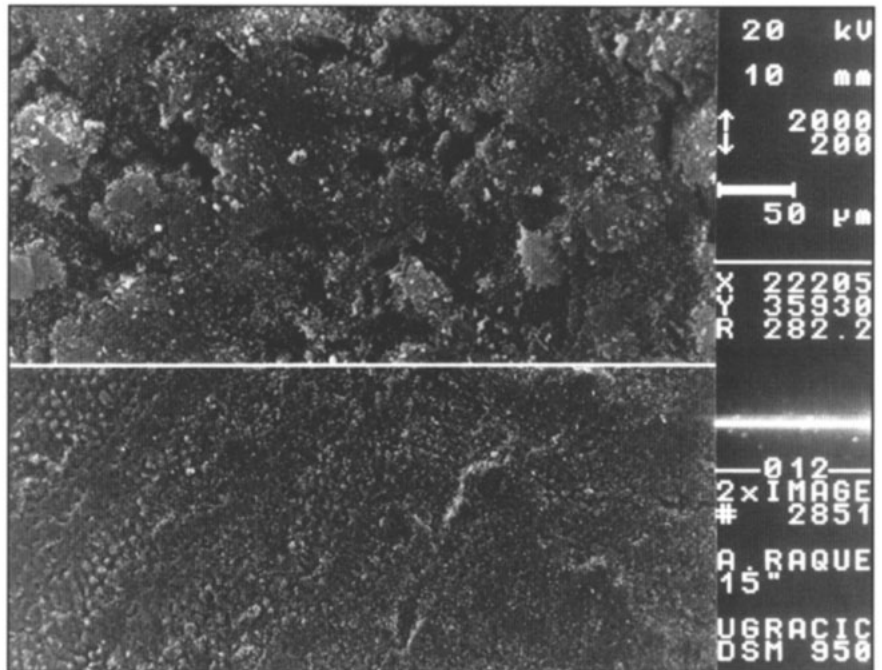


Figure 2

SEM micrograph of the enamel surface treated with a 37% phosphoric acid solution for 15 seconds (original magnification, top x2000, bottom x200).

Table 1
Mean shear bond strength (MPa) and standard deviation in two test groups

Etch time	Number of cases	Mean	Standard deviation	Standard error
60 seconds	30	12.15	4.25	0.77
15 seconds	30	9.38	4.35	0.79

t-value = 2.49; degrees of freedom = 57.96; *p*-value = 0.016.

Table 2
Failure sites for different etching times

Etch time	Failure site	
	Enamel-resin	combination
60 seconds	1	29
15 seconds	4	26

Chi-square = 0.87; *p*-value = 0.35.

strength (N/mm²) was then calculated on the basis of the bracket area.

Adhesive remnant index (ARI)

Immediately after bracket removal, the teeth were rinsed and dried using an air-water syringe. No attempt was made to remove any remaining adhesive until each tooth had been subjected to ARI assessment, calculated as follows:¹⁴

$$\text{ARI} = \frac{\text{Area of residual resin}}{\text{Area of bracket base}} \times 100$$

According to this definition, 100% indicates all the resin remains and 0% means none remains. The "area" in this formula was measured from photographs that were taken using standardized methods. Excess resin outside the bracket base was not studied. Specifically, the ARI was quantified as follows: standardized photographs were made of the surfaces of all specimens with a Nikon camera and a 4x macro lens. The images were transported to the computer and the ARI percentages calculated using Photoshop 2.0 program (Adobe Systems Inc, Mountain View, Calif) according to the above formula.

Enamel morphology evaluation

Enamel surfaces etched for 15 and 60 seconds were analyzed visually with a stereomicroscope and with a scanning electron microscope (SEM, Zeiss DSM 950, Germany). For SEM evaluation, two samples of each group were coated with gold to a thickness of approximately 50 Å in a vacuum evaporator. An accelerating voltage of 20 kV at x200 and x2000 was applied and both surfaces were

Table 3
Mean adhesive remnant index (%) and standard deviation in two test groups

Etch time	Number of cases	Mean	Standard deviation	Standard error
60 seconds	30	30.73	23.50	4.29
15 seconds	30	13.49	11.08	2.02

t-value = 3.63; Degrees of freedom = 41.28; *p*-value = 0.001.

photographed to demonstrate morphologic differences in the enamel surface. A consensus by the authors was obtained regarding the micro-morphologic observations.

Statistical analyses

Differences between groups of teeth (15- or 60-second etch time) in bond strength and in ARI were evaluated with a dependent *t*-test. The relationship between bond strength and ARI was assessed with a Pearson correlation test. The site of bond failure was evaluated statistically by χ^2 analysis. For statistical comparisons, the level of significance was predetermined at the 0.05 level of confidence.

Results

Shear bond strength

Mean shear bond strength and standard deviations of shear bond strengths for both groups are presented in Table 1. Student's *t*-test analysis showed a significant difference (*p* = 0.016). Shear bond strength was greater when the enamel surface was etched for 60 seconds.

The χ^2 analysis indicates that the site of bond failure during debonding does not vary significantly according to the etch time ($\chi^2_c = 0.87$;

p = 0.35). A combination bond failure was defined as a mixed phenomenon of bond failures occurring at the enamel-adhesive interface, at the bracket-adhesive interface, and within the adhesive resin. In this study combination bond failures occurred in 97% of cases when etching time was 60 seconds and 87% of cases when etching time was 15 seconds. In no case did failure occur at the bracket-adhesive interface.

In all groups, all bonding failures occurred at the enamel-resin interface (between the enamel and the resin). There was no bracket-resin failure in any group. Etching time had no effect on the bonding failure pattern (Table 2).

Adhesive remnant index

There were significant differences (*p* = 0.001) in the ARI for the two etching times tested (Table 3). The amount of adhesive remaining on the teeth was greater when the enamel surface was etched for 60 seconds.

There was no significant correlation between shear bond strength and adhesive remnant index calculated in the total of the sample (*r* = 0.017; *p* > 0.05).

Enamel morphology

Electron microscope photographs show that a reduced etch time created a smoother enamel surface; absolute enamel loss also decreased, which can be observed at 200x magnification (Figures 1 and 2).

Discussion

The results of this study show that etching the enamel for 60 seconds produces a statistically significant higher bond strength than etching for 15 seconds. However, the bond strength produced with the 15-second etch is still greater than that required for successful orthodontic bonding.⁸

The 15-second etch time produced a "cleaner" debonding site. More samples failed at the adhesive-enamel interface, which would leave the enamel surface relatively free of resin. This would provide the clinician with an easier and safer environment after orthodontic bracket removal. This was also confirmed with the SEM examination. The fact that no sample revealed bracket-resin failure may suggest that the retentive mesh of the brackets used was effective in retaining the resin and may differ from other brackets.

The present results on enamel surface morphology are in agreement with the results reported by Hallett et al.,¹⁵ who showed that prolonged etching times increase enamel surface roughness. Increased surface roughness renders the enamel more retentive and, in the present study, produced a higher bond strength. From a clinical standpoint, this may not be desirable. As Martin and García-Godoy¹⁶ have stated, high shear bond strength in orthodontics is not necessarily a beneficial property of an adhesive. They suggested that a weaker luting agent with a lower adhesive value might be preferable to increase failure or bracket debonding at the resin-enamel interface. In another study evaluating ceramic brackets, García-Godoy and

Martin¹⁷ suggested that, since bond strength without enamel etching was found to withstand orthodontic forces in vitro,¹² clinical studies without etching should also be done.

Based on the present results, a previously published review,¹² and clinical evaluations,^{11,13} lower etching time should produce acceptable results for metal bracket bonding.

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