ORIGINAL ARTICLE

Year : 2014 | **Volume** : 5 | **Issue** : 1 | **Page** : 67-70

The effect of using different rinsing angles on the micro-tensile bond strength of the sealant to the etched enamel

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DOI: 10.4103/0976-237X.128669

PMID: 24808698

Abstract

Background: Attempts to enhance bond strength of the sealant have been among the most important sides of dental research. **Aim:** The purpose of the present study was to evaluate the effect of using different rinsing angles on the micro-tensile bond strength of the sealant to the etched enamel. **Settings and Design:** Experimental study. **Materials and Methods:** Sixty first-premolars were randomly assigned to six groups based on the rinsing angle applied (15°, 30°, 45°, 60°, 75°, and 90°). Following etching and rinsing, a 4-mm height build up of sealant material was created. Bonded specimens were sectioned into sticks (1 X 1 mm), which were subjected to micro-tensile bond strength, testing at a cross-head speed of 0.5 mm/min. **Statistical Analysis Used:** The data were analyzed by Kolmogorov-Smirnov and post-hoc Tukey test. **Results:** The tensile bond strength in specimens rinsed at 90° were statistically higher compared to those rinsed at 15° and 30° ($P < 0.05$), and increasing the angle from 15° to 90° was correlated with a reduction in the number of specimens with adhesive failures. **Conclusions:** Rinsing the conditioned enamel surface at 90° may improve the bond strength and retention of the sealant.

Keywords: Bond strength, retention, rinsing angle, sealant

How to cite this article:
Afshar H, Nakhjavani YB, Ahmadi R. The effect of using different rinsing angles on the micro-tensile bond strength of the sealant to the etched enamel. Contemp Clin Dent 2014;5:67-70

How to cite this URL:
Afshar H, Nakhjavani YB, Ahmadi R. The effect of using different rinsing angles on the micro-tensile bond strength of the sealant to the etched enamel. Contemp Clin Dent [serial online] 2014 [cited 2014 Dec 9];5:67-70. Available

from: http://www.contempclindent.org/text.asp?2014/5/1/67/128669

Introduction

Dental surfaces with pits and fissures are susceptible for dental caries. [1] At the same time, the usual prevention measures against caries (topical and systemic fluoride therapy) have the lowest effects in these areas. [2] Sealants can seal the fissures and prevent microbial plaque colonization in their depth. [1] This advantage is enhanced through sealant strength in penetrating to the depth of the fissures and retention in the porosity of the etched enamel surfaces. [3],[4] The better the resin and the etched enamel contact, the more increased will be the adhesion of sealant to the enamel. Therefore, the cleaner the teeth surface, and the better etching, rinsing, and drying, the better resin can wet the etched enamel and penetrate into deeper depth. [5] The remains of the etching products will cause in lesser resin penetration in the etched enamel and causes lesser retention; [6],[7] therefore, the total eradication of dissolved calcium phosphate salts will result in improvement of sealant bond to the tooth. [6] The purpose of the present study is to assess the effect of different rinsing angles of the etched enamel to the bond strength between the tooth and the sealant.

Materials and Methods

In the present study, 60 first-maxillary premolars that had been extracted for orthodontic purposes were collected. All teeth were free of any caries, breakage, or enamel problems at buccal or lingual surfaces. Following rinsing with water, the teeth were kept in 0.5% chloramine T solution. Depending on the rinsing angle, the teeth were divided into 6 groups as follows: Group I (with a rinsing angle of 90°); Group II (with a rinsing angle of 75°); Group III (with a rinsing angle of 60°); Group IV (with a rinsing angle of 45°); Group V (with a rinsing angle of 30°); and Group VI (with a rinsing angle of 15°). Following this division, the teeth in each of the groups were sub-divided into two groups as follows: Buccal (5 teeth), and palatal (5 teeth) randomly. Next, the teeth roots were mounted in plaster blocks (Vel-Mix Stone, Kerr, Italy) with a diameter of 2.5 cm, and a height of 2 cm. They were mounted in such a way that the height of contour of the surfaces were almost in vertical positions. Two fissures, one vertically and one horizontally, were cut by a high speed hand piece to indicate the location which was etched and rinsed. By means of a low speed hand piece, the examination sites on the teeth were cleaned for 10 s. In this step, the teeth were microscopically tested for a second time to find any enamel problems. In order to clarify the rinsing angle exactly, a syringe on a moving protractor in a distance of 2 cm of the tooth surface was fixed [Figure 1]. A barometer, on the water pouring system, helped to uniform the water pressure, pouring on all samples. After 20 s of etching (by Scotch Bond, 3M, St Paul, MN, USA), the teeth surfaces were rinsed for 20 s at each of the angles mentioned above. The teeth were dried in such a way that the chalky-white enamel surface was visible. To put the sealants (Concise, 3M, ESPE, USA) on the etched surfaces, transparent plastic pipes with an internal diameter of 3.6 mm and a height of 4 mm were used. Finally, following sealant placing in the plastic cylinders and curing them, the plastic matrix was dissected by the scalpel blade and finally separated. A cylinder with a diameter of 3.5 and a height of 4 mm was remained on the buccal or palatal surface of the teeth. The roots were dissected from 2 cm below the C.E.J. by a diamond discus (DandZ Diamond, Germany) and separated. All samples were kept in distilled water for 24 h, before being prepared for micro tensile bond test.

The teeth were sectioned in X and Y directions to obtain bonded sticks with a cross-sectional area of approximately 1.0 mm2, measured to the nearest 0.01 mm with a digital caliper (Mitutoyo Corp, Japan).

Figure 1: A water syringe mounted onto a protractor to determine the exact rinsing angle

The samples were then fixed on the plate of the micro tensile test machine (Bisco Inc., USA) conforming to the midline of the plates. In this machine, a pulling strength of 200 N with a speed of 0.5 mm/min was exerted to the samples. The load (N) and the bonding surface area of the specimens in mm ^{2} were noted and the micro tensile bond strength calculated in MPa.

The type of failure in the samples was determined at a magnification of 90 × by stereo microscope (SZX Olympus, Japan). The failure mode was classified in three forms as follows:

- Adhesive; failure between the enamel and the sealant
- Cohesive; failure inside the sealant
- A mixed form of adhesive and cohesive.

In the case of a mixed failure mode, the amount of the remaining composite on the surface was calculated by a grid lens and expressed in %.

Data analyses

Data were analyzed using SPSS statistical software. The normal distributions of bond strength and sealant remnant were verified using the Kolmogrov-Smirnov test and an all pair-wise multiple comparison post-hoc Tukey test was used to determine the statistical significance between the groups. Mode of failure data were subjected to the Chi-square test. The level of statistical significance was set at 5%.

Results

The results concerning the tensile bond strength of the samples MPa (Mean S) are shown in [Table 1]. Tukey HSD Test showed that the tensile bond strength in the Group I was significantly higher than those in Groups V and VI (*P* < 0.05).

Rinsing angle	μTBS mean±SD	Z	*P* value
90°	24.98±1.4	0.542	0.931
75°	24.26±1.17	0.674	0.754
60°	23.95±1.39	0.619	0.838
45°	23.97±1.24	0.574	0.897
30°	23.38±0.87	0.416	0.995
15°	23±0.81	0.423	0.994

TBS: Tensile bond strength; SD: Standard division

Table 1: Kolmogroy-smirnov test results on the amount of tensile bond strength in different rinsing angles

The percentage values of different failures at various rinsing angles and in total are demonstrated in [Table 2]. The most prevalent failure in the present study was a 'mixed' one. The lowest failure % was of 'Cohesive' type. Furthermore, an increase in the rinsing angle from 15° to 90° is associated with a reduction in the number of specimens with adhesive failures and an increase in 'Mixed' and 'Cohesive' failures [Figure 2]. Based on [Table 3], the highest average of residual composite percentage was at 90°, while the lowest was at 15°.

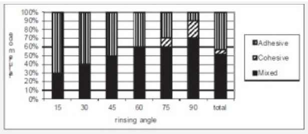

Figure 2: Comparison of failure modes in different rinsing angles

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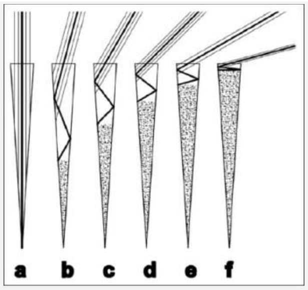

Figure 3: The possible effect of different rinsing angles on removing the etch products. The mottled area shows etching products remaining after rinsing in each group. a: 90°, b: 75°, c: 60°, d: 45°, e: 30°, f: 15°. Increasing the angle from 15° to 90° results in discharging of more precipitates from the resin tags

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Failure type	90°		75°		60°		45°		30°		15°		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
c/a*	7	70	6	60	6	60	5	50	4	40	3	30	31	51.7
c†	2	20	1	10	0	0	0	0	0	0	0	0	3	5
a‡	1	10	3	30	4	40	5	50	6	60	7	70	26	43.3
Total	10	100	10	100	10	100	10	100	10	100	10	100	60	100

*c/a: Mixed failure; †c: Cohesive failure; ‡a: Adhesive failure

Table 2: Percentage of different failures at various rinsing angles

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Rinsing angle	Composite (%)	Z	P value
90°	63.9±28	0.871	0.434
75°	44.6±38	0.927	0.357
60°	34.5±35	0.752	0.624
45°	31.5±34	1.022	0.247
30°	22.8±30	1.177	0.125
15°	12.2±20	1.357	0.05

Table 3: Kolmogrov-smirnov test results on the % of the residual composite at different rinsing angles

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Discussion

The intention of this study was to improve caries preventive effect of sealants by improving their adhesion to the underlying enamel. A move in this direction is needed as the interest of the dental profession in preventive dentistry is increasing. Considerable research has been undertaken to optimize the bond strength between resin-based dental materials and dental enamel. The ability of the resin to penetrate between the enamel crystallites and rods is a determinant of the bond strength between the resin and the etched enamel. [8] To enhance the enamel surface free-energy and resin penetration, it is important to remove all etched remnants in the enamel porosity. [6]

Here we showed that a general trend exists between reduction in bond strength and the rinsing angle from 90° to 15° [Table 1]. It seems that the increased tensile bond strengths, associated with the more thorough washing, were due to the increased rinsing angle. As shown in [Figure 3], at 90°, the complete evacuation of the etching products can be achieved, while the persistence of deposit remnants on enamel surface might possibly be a consequence of reduction in the rinsing angle. These data, therefore, support the hypothesis that failure to remove the etched enamel surface deposits markedly reduces bonding between the sealant and the enamel. Indeed, scanning electron microscopy of etched enamel surfaces has shown the presence of such deposits after inadequate washing. [6]

Incomplete cleansing obscures the fine structure of the etched prism by a generalized precipitate layer so that the surface does not lend itself to mechanical bonding. [8]

The efficacy of sealants and resins has been evaluated by numerous mechanical testing methods, such as shear bond strength, tensile bond strength and micro-leakage. [4] In this study, we used the micro tensile technique, a recent but widely employed test to evaluate the bond strength of adhesive materials to dental tissues. [9],[10] Compared to other debonding tests, this method tends to increase adhesive failures. [9] Because of the small size of the specimens in the micro tensile test, stress distributions are improved and failures occur in materials with true ultimate strength closer to the applied load. [9] Thus, identification of the site where failure has occurred is important. In our study, the mean micro tensile bond strength varied between 23 and 24.98 Mpa [Table 1]. In spite of such high bond strength, no cohesive failure was observed in the enamel. This behavior may be attributed to the micro tensile test characteristics, which have been shown to produce a more homogeneous stress distribution and to the prismatic orientation of the intact enamel surface, which is mostly perpendicular to the enamel periphery and parallel to the applied stress. [10] These will result in higher bond strength and fewer cohesive failures. [9],[10] In a study conducted by Giannini *et al*., on the ultimate tensile strength of tooth structures, they found that intact enamel when stressed transversely to its prismatic orientation, is significantly weaker compared to when stressed parallel. [10]

A possible explanation for the cohesive failures (in adhesive material) in Groups I and II [Figure 2] may be the higher bond strength in these groups, which was probably stronger than the ultimate tensile bond strength of the adhesive, [3],[9] leading to failures in sealant material. A reduction in the rinsing angle was coupled with more adhesive failures, which would be attributable to the lower bond strength observed in acute angles.

Light stereo microscopy of the specimens revealed that the presence of more sealant remnants at the failure site when a rinsing angle of 90° was used. Furthermore, the percentage resin remnants decreased with a reduction in the rinsing angle. This indicates that bond failures in acute angles occur more frequently at the enamel adhesive interface consistent with the other findings in this study, showing that rinsing at 90° results in improved adhesion of sealant to the enamel surface. It should be further noted that in view of the fact that many researchers consider a clinically successful bond as being between 15 and 35 Mpa, [7] it seems that there were acceptable bond strengths in the acutest rinsing angles. We did not observe any premature fractures in our study in contrast to some other investigations. [3],[11],[12],[13] According to the literature, premature failure occurs in very low tensile strengths (5-7 Mpa) or in high cutting speed during specimen preparation. [11],[12] To avoid this problem, we have used a low cutting speed with a coolant spray and a very thin cutting blade (0.3 mm) during sample preparations.

Since many variables encountered in the clinical cases cannot be controlled for *in-vitro*, we are unable to make direct inferences from the information obtained in this study to the clinical cases. Therefore, future clinical trials that assess the longevity of sealants placed subsequent to washing with different rinsing angles are necessary.

Conclusion

Within the limitations of this *in-vitro* study, the following conclusions can be drawn:

- Rinsing the etched enamel surface at an acute angle (15° and 30°) reduces the bond strength
- A direct relationship existed between the rinsing angle and percent values of sealant remnants on the tooth surface after failure, contributing to the bond strength of each group
- However, there will be acceptable bond strengths in the acutest rinsing angle.

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