Effects of fluoride application on shear bond strength of orthodontic brackets

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The technique of bonding orthodontic brackets to teeth with resin was introduced in 1964.[1] The procedure incorporated the use of an acid-etch technique to better adhere the brackets to enamel.[2-8] Since those earlier stages, clinicians have searched for ways to preserve enamel morphology without compromising bond strength. Techniques varying from decreasing etching times and concentrations[9,10] to using prophylaxis agents containing fluoride[11-13] have been evaluated. Fluorides react with the enamel surface to form calcium fluoride and fluoroapatite, making the surface more resistant to demineralization and decay.[14]

Clinically, the overall failure rate for brackets bonded directly to enamel has been reported to range from 4% to 30%.[15] Factors that could alter bond strength include contaminants, such as saliva, and the contents of some pastes, such as fluorides, oils, or other agents.[10,16-19] Gwinnett et al.[16,17] found that certain topically applied fluorides could significantly reduce bond strength by disrupting the formation of enamel tags.[18,19] However, in other studies where pumice and fluoridated prophylaxis pastes[13] or fluoride solutions were used following acid etching,[20] shear bond strength was not significantly affected. The conflicting findings may be the result of a num-

Abstract

The purpose of this study was to determine the shear bond strength and debonding failure modes of orthodontic brackets bonded to teeth that have been treated with various fluoride concentrations. Thirty-six recently extracted human premolars were divided into three groups: prophylaxis with pumice only, prophylaxis using a 13,500 ppm fluoridated pumice, and prophylaxis with pumice followed by application of a 2500 ppm fluoridated paste. The teeth were etched with a 37% phosphoric acid gel, then bonded with a metal orthodontic bracket. The teeth were mounted in phenolic rings and stored in de-ionized water at 37°C for 72 hours. A Zwick Universal Testing Machine was used to determine shear bond strengths. The residual adhesive on the enamel surface was estimated using the Adhesive Remnant Index. Analysis of variance was used to compare the various groups, and significance was predetermined at $p \leq .05$.

The results indicate that there were no significant differences in bond strengths between the treated and untreated teeth ($p = .233$). The Chi Square test evaluating the residual adhesive on the enamel surfaces also showed no significant differences ($p = .456$). In conclusion, the use of fluoridated prophylactic pastes with varying fluoride concentrations does not significantly affect shear bond strength or bond failure location.

Key Words

Bonding • Fluorides • Shear strength

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Table 1
Descriptive statistics and results of comparisons of the shear bond strengths (MPa) for the three groups compared.

Group Tested	N	$\bar{X}$	SD	Range	F-value	P
Pumice only	12	11.8	4.1	6.4-19.1		
2500ppm fluoride	12	10.6	2.2	6.6-14.2	1.48	.233
13,500ppm fluoride	12	9.5	3.2	5.7-14.9		

$\bar{X}$ = mean; SD = standard deviation; P = probability

Table 2
Adhesive Remnant Index (ARI) scores for the three groups.

Group	Adhesive Remnant Index ratings 1	2	3	4	5	Chi Square
Pumice only	0	5	6	1	0	$X^2 = 8.795$
2,500ppm fluoride	1	8	3	0	0	p = .456
13,500ppm fluoride	0	9	3	0	0	

1, All composite remains on the tooth; 2, more that 90% of the composite remains on the tooth; 3, more than 10% but less than 90% of the composite remains on the tooth; 4, less than 10% of the composite remains on the tooth; 5, no composite remains on the tooth.

ber of factors, including variation in the fluoride concentrations used by different researchers and improvements in the properties of the bonding agents and/or the bracket-retention mechanism.

The purpose of the present study was to determine the shear bond strength and debonding failure modes of orthodontic brackets that were bonded to enamel following the application of various fluoride concentrations.

Materials and methods

Thirty-six recently extracted human premolars were collected and randomly divided into three groups. The teeth were stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included: intact buccal enamel, no exposure to any pretreatment chemical agents, e.g., hydrogen peroxide, no cracks due to extraction forceps, and no caries. The teeth were cleansed and then polished for approximately one minute with either pumice only, prophylaxis using a 13,500 ppm fluoridated (NaF) pumice (Nupro, Johnson and Johnson Dental Products Co, East Windson, NJ), or prophylaxis with pumice followed by the application of 2500 ppm fluoridated (NaF) paste (Fluocaril, Laboratoires Pharmaceutiques Goupil, Paris, France).

The teeth were etched with a 37% phosphoric acid gel applied to the buccal surface for 30 seconds, then rinsed with a water spray for 30 seconds and dried with an oil-free air source for 20 seconds.

Systems 1+ bonding adhesive (Ormco Corporation, Glendora, Calif), was used to bond metal orthodontic brackets (3M Unitek, Monrovia, Calif) to each tooth according to the manufacturer's instructions. A force of 300 grams was applied to each bracket, and the excess bonding resin was removed with a small scaler. The bracket base surface area was determined to be an average of 12.21 mm^2.

A mounting jig was used to align the buccal surfaces of the teeth perpendicular to the bottom of the acrylic mold. The teeth were placed in phenolic rings (Buchler, Ltd., Lake Bluff, Ill) embedded up to the cementoenamel junction and then stored in deionized water at 37°C for 72 hours. The buccal surface of each tooth was aligned to the testing device so that the force was parallel to the surface during the shear force test.

A Zwick Universal Testing Machine (Calitek Corp, Riverview, Mich) was used to measure the shear bond strengths. A perpendicular force was applied from the machine to the bracket by a flat-end steel rod that produced a shear force at the bracket-tooth interface. The result of each test was recorded on a computer connected to the Zwick machine.

The residual adhesive on the enamel surface following debonding was evaluated using the Adhesive Remnant Index (ARI). The rating assigned to each tooth varied from 1 to 5, with 1 indicating that all the composite remained on the enamel surface; 2, more than 90% of the composite remained; 3, more than 10% but less than 90% remained; 4, less than 10% remained; and 5, no composite remained on the tooth.

Statistical analysis

The descriptive statistics for the debonding strengths of the three groups was calculated and recorded in MPa (N/cm^2), and the analysis of variance was used to compare the various subgroups tested. A multivariate analysis of variance was performed for the full model. If significant differences were found, Duncan's Multiple Range test was used to determine which of the means were significant. The Chi Square test was used to evaluate differences in the ARI scores between the groups. The significance for both tests was predetermined at $P \leq 0.05$.

Results

Descriptive statistics, including the mean, standard deviation, and minimum and maximum

values for each of the three groups are presented in Table 1. The results of the analysis of variance indicated that no significant differences were present in bond strengths between the fluoride- and non-fluoride-treated groups (P = .233)

The residual adhesive on the enamel surfaces, as indicated by the ARI scores, are presented in Table 2. The Chi Square test results indicated that no significant differences (P = .456) were present between the various groups.

Discussion

Preparing and cleaning the enamel surface before applying the etchant is an integral part of the procedure for bonding orthodontic brackets to enamel surfaces. Earlier studies suggested that the use of topical fluoride reduces bond strength. Gwinnett and Smith[21] reported that prophylaxis before acid-etching is recommended to remove plaque and other acquired debris, but that certain topically applied fluorides could reduce bond strength. As a result, prophylaxis with fluoride pastes before acid-etching or the application of fluoride solutions after etching were not routinely recommended. This is despite the fact that other studies have indicated that fluoride does not significantly affect bond strength.[11-13,22,23] In addition, the use of topical fluoride has been established as effective in reducing decalcification and decay.[24]

The results of this study indicate that shear bond strength is not significantly affected when the enamel surfaces have been treated with various concentrations of fluorides. The group treated with pumice only had the highest bond strength (11.8 MPa), followed by the 2500 ppm fluoride group (10.6 MPa), then the 13,500 ppm fluoride group (9.5 MPa). The decrease in bond strength as the fluoride concentration increased was not statistically significant, and all values were clinically acceptable.

The ARI scores for the three groups showed no significant differences. The majority of scores ranged between 2 and 3 for all the groups, indicating that most of the composite remained on the enamel surfaces after debonding. This further indicates that, in general, the bond between the resin and the enamel was stronger than the bond between the bracket and resin.

Conclusions

Treating enamel with fluoridated prophylactic pastes of varying fluoride concentrations does not significantly affect shear bond strength or bond failure location during the removal of orthodontic brackets. As a result, the use of fluoridated prophylaxis products to clean the teeth before acid-etching should not be discouraged as part of the bonding protocol.

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