The effect of enamel preparation on the tensile bond strength of orthodontic composite resin

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The introduction of resin bonded brackets by G.V. Newman in 1964 revolutionized the practice of clinical orthodontics.[1] Newman incorporated the acid etch procedure developed by Buonocore to facilitate bonding of the orthodontic bracket to the enamel surface.[2-5] The technique used by Newman was modified to include use of a bis-GMA resin, as opposed to an epoxy-based resin.[3] This system, as reported by Gorelick, is still used by the majority of orthodontists.[6]

Buonocore proposed the use of 85% orthophosphoric acid for 30 seconds to etch the enamel surface.[7] Extensive research has been conducted to determine the optimal acid concentration and exposure time for treatment of the enamel surface.[5] Phosphoric acid concentrations of 30-60% are generally used to etch the enamel surface, with the recommended exposure time varying from 30-60 seconds.[5] This is despite the fact that several investigators have shown no significant difference in the bond strength with an exposure time of less than 30 seconds.[4,8-9]

Traditionally, bonding resins have consisted of a two-paste system. "No-mix", or one-paste, resins have been introduced relatively recently. These one-paste resins offer advantages such as less waste, easier debonding and longer working time when compared to the two paste systems.[10] However, the

Abstract

The bonding of orthodontic brackets to enamel surface using bis-GMA composite resin is usually accomplished by first cleaning the tooth surface then etching with phosphoric acid. This study compared the tensile bond strength of composite resin applied to a tooth surface which had been cleansed with an air-powder polisher to that of the same resin applied to a surface cleansed using a rubber cup and pumice. A wire loop apparatus was attached to bonded orthodontic brackets and pulled in tension in order to test the adherence of the bracket to the tooth. Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used to evaluate the tooth surface to determine whether sodium bicarbonate material remained after the cleaning operation. All data was analyzed by the one way analysis of variants, the Student-Newman-Keuls test and Duncan's multiple comparison test.

No statistical differences were found between the tensile strength of the bonds on the teeth cleansed with the air-powder polisher and those cleansed with a rubber cup and pumice. However, a double exposure of the tooth to phosphoric acid may lower the tensile bond strength by a significant amount.

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Key Words

Tensile bond strength ● Orthodontic brackets ● Air-powder polisher ● Enamel surface preparation ● Sodium bicarbonate residue ● Orthodontic composite resin

Table I
Enamel Cleansing and Etching by Group

Group	Enamel Cleansing	Acid Etching
A	Rubber Cup and Pumice	One 30-second exposure
B	Air-Powder Polisher	One 30-second exposure
C	Air-Powder Polisher	Two 30-second exposures

Table I
Test groups, number of samples in each group, method of enamel cleansing for each test group and acid etch exposure.

two-paste systems offer higher bond strength, with a failure rate of only 1%.[10-11]

The initial step in bonding an orthodontic bracket is to thoroughly clean the enamel surface. This is usually accomplished with a rubber cup and flour of pumice.

An alternative method for cleansing the enamel surface is the air-powder polisher. This instrument was first introduced in 1977 by Dentsply, and has been shown to be an effective method for plaque and stain removal in clinical situations.[12-15] In a number of reports the air-powder polisher has been shown to be as effective as the use of a rubber cup and pumice in plaque and stain removal.[12-14] In view of this, the air polisher may provide an alternative in clinical situations traditionally reserved for a rubber cup and pumice.

Interestingly, use of the air powder polishing device has been shown to produce a non-uniformly roughened enamel surface without causing any deleterious effects.[14,16-17] Although an increase in surface roughness can be seen under the scanning electron microscope, only minimal enamel is actually removed. Unfortunately, the effects of the air polisher on the cementum are more pronounced, as the device has been shown to remove significant amounts of root surface.[14]

Additionally, the air polisher has a highly abrasive effect on the surface of composite restorations, while there is a minimal effect on the surface of metallic and ceramic restorations.[13,18-19] Direct contact of the air polishing spray on composite resins should be avoided.[13]

Some reports suggest the air-powder polisher is indicated for use in plaque and stain removal as part of a dental prophylaxis or in preparing the tooth for acid etching prior to sealant placement. Scott and Greer found adhesion of a sealant to the enamel surface to be equivalent whether the enamel was cleansed with the air polisher or a rubber cup and pumice.[15]

The air polisher is commonly used in general and periodontal practices, but has received little attention in the orthodontic literature. Barnes et al. found the device to be the most effective method of stain and plaque removal in bonded and bracketed patients.[13] The instrument did not cause breakage of elastics or arch wires. However, little documentation exists concerning the application of the air-powder polisher for surface cleansing prior to bracket placement.

The air polishing device has several advantages: it is more effective and more time efficient than the rubber cup and pumice and it generates no heat.[13,18,20] Deposits are removed from the tooth surface by a stream of sodium bicarbonate particles sprayed with water and compressed air onto the tooth surface. The air/water spray is typically under a pressure of 65-100 p.s.i. Sodium bicarbonate is only mildly abrasive and is biocompatible if a small amount is ingested.

While the air polishing instrument remains an effective and efficient means of tooth surface cleansing, some safety precautions must be followed. The operator should wear a mask and protective eyewear due to the aerosol production. Protective eyewear should also be provided for the patient.[14-5,20] The patient's lips should be lubricated to counteract the desiccating effect of the sodium bicarbonate.[14,20] Likewise, the patient should not wear contact lenses while the device is in use.[14-5,20]

Relatively few health risks have been documented with use of the air-powder polisher. However, reports indicate that use should be avoided in patients with respiratory diseases, hypokalemic patients, patients suffering from renal insufficiency or chronic diarrhea, patients taking medications which may alter the electrolyte balance and patients on long-term steroid therapy.[15,17,20]

Prudent use of the air polishing device allows for effective plaque and stain removal in a timely manner. The air polisher has been shown to be effective in enamel cleansing prior to acid etching in sealant application.[15] However, no documentation exists concerning the effect on the adherence of orthodontic brackets when the enamel is cleansed with an air polisher rather than a rubber cup and pumice prior to etching. In addition, no documentation is available concerning the effect of any residual sodium bicarbonate on the efficacy of the phosphoric acid etch.

The purpose of this study was two-fold. The first objective was to evaluate the tensile bond strength of brackets placed on teeth which were cleansed with an air-powder polisher prior to etching the enamel surface. Surface cleansing with a rubber cup and pumice in the traditional manner was performed as a control. The second objective was to test the tensile bond strength of the brackets on teeth which were cleansed with the air polisher and then etched twice prior to bracket placement. In this way we hoped to show what effect, if any, the alkaline nature of the sodium bicarbonate had on the capacity to form an effective bond to the enamel surface.

Materials and methods

Sixty extracted maxillary lateral incisors were selected for this study. The teeth were stored in formalin prior to use. The roots were removed prior to the start of the study and the incisal, gingival, mesial and distal surfaces were wet ground using 180 grit SiC paper. This was done to provide parallel surfaces to allow ease of gripping and positioning in the jaws of the Instron Universal Testing Machine (Instron Corporation, Canton, Mass). The facial surface of each tooth, to which the bracket was to be bonded, was not ground or altered in any manner.

The teeth were divided into three test groups. In the control group, Group A, the enamel surface of each tooth was initially cleansed with a rubber cup and flour of pumice. In Groups B and C the teeth were initially cleansed with an air polishing instrument (Prophy-Jet, Dentsply/Equipment Division, York, PA) (Table I).

The facial enamel of each tooth was cleansed for 30 seconds with either the rubber cup and pumice or the air-powder polisher to insure removal of all surface contaminants. A circular motion was used with each method to avoid damage to any area of the enamel. A thorough rinsing with water for 20 seconds was provided for each specimen. Teeth were allowed to air dry to eliminate the possibility of contamination from the air line.

A 37% phosphoric acid solution was used to etch the facial surface of each tooth. The etchant was applied to that portion of the enamel where the orthodontic bracket was to be placed. Each tooth was initially exposed to the etchant for 30 seconds, followed by a thorough rinsing. The specimens were allowed to air dry. Those teeth in Group C were re-etched with the phosphoric acid for an additional 30 seconds then rinsed and dried as previously described.

The brackets were bonded with the Concise Orthodontic Bonding System (3M/Dental Products Division, St. Paul, Minn.) The Concise system consists of a two-liquid unfilled resin and a two-paste filled material. The material is a composite of bis-GMA and triethylene glycol dimethacrylate with quartz filler particles.[21]

Ormco non-angulated, non-torqued, twin, mesh-backed brackets (Ormco, Glendora, Calif.) were used for each sample. The brackets have a 100 gauge mesh backing and a 0.022 x 0.028 inch edgewise slot. The surface area is 0.027 in^2 or 0.174 cm^2 for each bracket.[22]

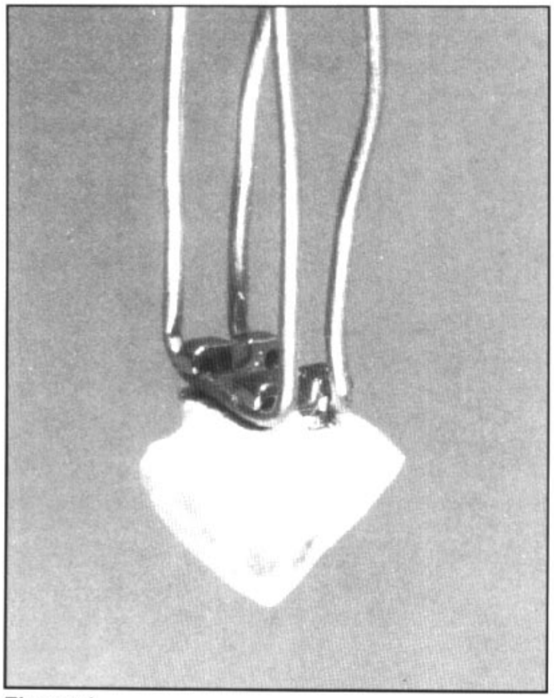

Figure 1

Figure 1
Wire loop apparatus attached under wings of orthodontic bracket and ready for placement in Instron unit.

A thin layer of the unfilled resin was applied to the etched enamel. The filled resin was mixed and applied to the mesh backing of the orthodontic bracket. Each bracket was firmly seated onto the enamel. Excess composite resin was removed immediately. The composite material was allowed to set for 10 minutes on the bench top prior to moving the specimens. All samples were placed in distilled water, at 70° F and stored for two weeks.

The tensile bond strength of each specimen was tested on the Instron Universal Testing Machine. The Instron unit was driven at a cross head speed of 0.02 in/min. Each specimen was placed directly into the lower jaws of the Instron. The jaws were tightened sufficiently to prevent slipping. A wire loop device which locked under the wings of the orthodontic bracket was fabricated (Fig. 1). This device was attached to the upper jaws of the Instron to insure equal distribution of forces. The Instron reading in pounds was divided by the bonded area (0.027 in^2) and the data was converted into megapascals.

The site of bond failure was determined for each sample using the adhesive remnant index (ARI). This index allowed for assessment of the amount of composite which remained on the enamel surface after bond failure (Table II).

The data for the tensile bond strength and the ARI were analyzed by the one way analysis of variance (ANOVA). In addition, the Student-Newman-Keuls (SNK) test and Duncan's multiple comparison test were used.

Table II
Adhesive Remnant Index (ARI)

Score	Definition
0	No adhesive left on tooth
1	Less than half of the adhesive left on tooth
2	More than half of the adhesive left on tooth
3	All adhesive left on tooth, with a distinct impression of the bracket

Table III
Tensile Bond Strength Data

Group	No.	Mean (MPa)	SNK*	Duncan's**	p(ANOVA)
A	19	3.83±1.51	|	|	0.055
B	19	3.75±1.10	|	|	
C	19	2.86±1.10	|	•	

* Vertical line connects groups which were not significantly different by SNK
** Vertical line connects groups which were not significantly different by Duncan's

Table II
Definition of grading of Adhesive Remnant Index as proposed by Artun and Bergland in 1984.

Table III
Tensile bond strength data and statistical analysis by test groups.

A scanning electron microscope (SEM) (ISI 100-B, International Scientific Instruments, Pleasanton, Calif.) was used to visually evaluate the tooth surfaces before and after treatment. Several teeth were randomly selected from each test group for evaluation. These specimens were mounted on aluminum stubs and coated with a thin layer of gold-palladium prior to examination. The specimens were also evaluated by energy dispersive spectroscopy (EDS) (PGT System 4, Princeton Gamma Tech, Princeton, NJ) in order to determine whether any sodium bicarbonate remained on the enamel surface prior to etching with the phosphoric acid.

Results

The mean and standard deviations for the tensile bond strength, in megapascals, of the control group and the two experimental groups are given in Table III. A one way analysis of variance and the Student-Newman-Keuls test indicate no significant difference between Groups A, B and C. However, Duncan's multiple range test does report a difference statistically between Group C and the other two.

Results of the Adhesive Remnant Index (ARI) are presented in Table IV. The distribution of samples for each group according to the appropriate ARI category is presented. All statistical tests on the ARI were performed on ranks. No adhesive remained on the tooth surfaces of 80% of the teeth in Group C. The amount of composite resin remaining on the enamel surfaces of the teeth in Group A (the control group) and Group B varied more widely. The ANOVA showed that a significant difference existed ($p = 0.0045$). Both multiple comparison tests (SNK and Duncan's) showed a difference exists between Group C and the other two groups, with respect to the ARI (rank). No statistical difference was found between the control group (Group A) and Group B.

Since this study indicated no difference between groups, statistical power was examined and estimated to be approximately 85%. Thus, if a significant difference (>1.28 MPa) existed for tensile strength values, the study was 85% likely to find this difference.

Analysis using the SEM failed to show any sodium bicarbonate material contaminating the enamel surface, nor were any particles found to be embedded into the enamel. These results were confirmed by the EDS analysis of the tooth surface.

Discussion

This study had two objectives. The first objective was to determine whether the tensile bond strength of the orthodontic bracket to tooth surface would be affected by cleansing the tooth surface with an air-powder polisher (APP), as in Group B, prior to bracket application as opposed to using a rubber cup and pumice (RCP), as in Group A. The results of this study indicate there is no difference in the tensile bond strength of those teeth cleaned with the APP versus the standard RCP.

Similarly, cleansing the surface with the APP prior to bracket placement does not appear to affect the site of bracket failure. Many reports have shown failure of the system can occur at the tooth-resin or resin-bracket interface. The results of Group A and B show failure at both these interfaces under stress. Thus the mode of failure appears to be the same for those teeth exposed to an enamel cleansing with the air-powder polisher prior to bonding of the bracket to the tooth and those teeth treated in a traditional manner.

In each instance, the data were initially evaluated by the one way analysis of variance. As a significant difference between groups was shown for the adhesive remnant index, and a tendency toward a significant difference was indicated with respect to the tensile bond strength, use of a multiple comparison test was indicated to further evaluate the data. This was necessary to determine whether a difference was truly present. Duncan's multiple comparison test is a relatively powerful test. The Student-Newman-Keuls test is a much more conservative test and thus a wider range of means is required to show a significant difference.

Interestingly, there does not appear to be a correlation between the tensile bond strength and the ARI. One cannot, under the conditions in this study, predict the site of failure of a bonded bracket for a given force applied in a tensile mode. Tensile bond strength differences of less than 1 MPa are functionally equivalent. This experiment was designed to provide 80% power to discriminate a statistical difference at that level.

Additionally, tensile bond strength is significantly reduced when the enamel is etched twice (Group C) prior to bracket placement. The data also indicate that the bond is weakened at the resin-enamel interface. This implies the additional exposure to the etchant may actually weaken the bond of the resin to the enamel.

As one premise of this study was that some sodium bicarbonate may remain on the surface of the roughened enamel prior to etching, a double etching was proposed to insure that the enamel was properly etched. The findings of this study indicate the additional exposure to the etchant is not beneficial, and may be detrimental, to the enamel-resin bond. Analysis by SEM and EDS indicate that no sodium bicarbonate particles remain on the tooth surface to affect the tensile bond strength. The sodium bicarbonate particles may be too soft to become embedded in the harder enamel surface. Also, it is likely that the surface roughness of the tooth during use of the air polisher is not sufficient to trap sodium bicarbonate particles. This roughness also does not appear to directly enhance the mechanical lock of the composite resin into the enamel. A single exposure to the phosphoric acid is significant to achieve a clinically acceptable bond strength when compared to a control.

Table IV
Adhesive Remnant Index Data

Group	No	ARI-No.	SNK*	Duncan's**	p(ANOVA)
A	19	0 - 7	│	│	
		1 - 3	│	│	
		2 - 2	│	│	
		3 - 7	│	│	
B	19	0 - 4	│	│	}
		1 - 7	│	│	0.0045
		2 - 2	│	│	
		3 - 6	│	│	
C	16	0 - 13			
		1 - 3			
		2 - 0	•	•	
		3 - 0			

* Vertical line connects groups which were not significantly different by SNK
** Vertical line connects groups which were not significantly different by Duncan's

Table IV
Adhesive Remnant Index data and statistical analysis by test groups.

Conclusions

The data in this study indicate there is no effect upon the tensile bond strength when the enamel surface is cleansed with an air-polisher prior to bracket placement. Neither does there appear to be an effect upon the site of bond failure when using the air-powder polisher versus the rubber cup and pumice for enamel preparation.

The air-powder polisher is an effective and efficient method of cleansing the enamel prior to bracket placement without compromising the tensile bond strength of the composite resin. In addition, no improvement in tensile bond strength was seen with the second exposure of the tooth to phosphoric acid. It is sufficient to etch the enamel once with phosphoric acid following use of the air polisher, despite the alkaline nature of the sodium bicarbonate. If any sodium bicarbonate remains following enamel surface cleansing, it is removed during the rinsing process, thereby having no effect upon the tensile bond strength of the resin material.

The air powder polisher can be recommended as an efficient and effective alternative to the rubber cup and pumice in enamel preparation prior to placement of orthodontic brackets. Cleansing with the air polishing device has no detrimental effect on the bond strength of the orthodontic bracket to the enamel surface.

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