Original Article

Effects of Potassium Nitrate and Oxalate Desensitizer Agents on Shear Bond Strengths of Orthodontic Brackets

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ABSTRACT

Objective: To evaluate the effects of potassium nitrate and oxalate desensitizer agents on shear bond strengths of orthodontic brackets.

Materials and Methods: Forty-five extracted human premolar teeth were randomly assigned to three groups of 15 each. UltraEZ potassium nitrate desensitizer was applied on teeth in the first group, while BisBlock oxalate desensitizer was applied on teeth in the second group. The third group served as a control. Orthodontic brackets were bonded with a light cure composite resin and cured with a halogen light. After bonding, the shear bond strength of the brackets was tested with a universal testing machine.

Results: The highest shear bond strengths were measured in Group III. The shear bond strength in Groups I and II was significantly lower than in Group III ($P < .001$). Significant difference was also found between Group I and Group II ($P < .01$).

Conclusions: Orthodontic brackets bonded to enamel treated with potassium nitrate and oxalate desensitizers showed significantly lower bond strengths than did brackets bonded to untreated enamel.

KEY WORDS: Tooth sensitivity; Dentinal hypersensitivity; Desensitizer; Oxalate; Potassium nitrate; Shear bond strength

INTRODUCTION

"Dentinal hypersensitivity" or "tooth sensitivity" is generally characterized by a short, sharp pain arising from exposed dentine in response to either cold, hot, toothbrushing, or sweet stimuli.[1–6] Several theories have been suggested to explain the mechanism of tooth sensitivity, but the "hydrodynamic theory" is widely accepted as the cause.[7,8] According to this theory, when the fluids within the dentinal tubules are subjected to temperature or physical osmotic changes, the movement stimulates a nerve receptor sensitive to pressure, which leads to the transmission of the stimuli.[6,9]

Despite the fact that this condition is either underreported by the dental patient population or misdiagnosed, its prevalence has been reported as high as 14.3% of all dental patients,[10] between 3.8% and 57% of the adult dentate population,[2,5] and up to 30% of adults at some time during their lifetime.[11] The greatest prevalence of dentinal hypersensitivity was reported between the third and fourth decades of life.[4] Most commonly affected teeth are the upper premolars, followed by the upper first molars, with the incisors being the least sensitive.[5]

Excessive dietary acids, toothbrush abrasion, chemical erosion, gingival recession, exposed dentin, and eating disorders have been identified as potential risk factors.[6,7,12,13] Patients undergoing surgical or nonsurgical periodontal treatment are susceptible to hypersensitivity because of the loss of cementum or gingival recession.[5,14,15] Also, patients might experience tooth sensitivity during or after bleaching procedures.[16–18]

Dental professionals can initiate treatment by (1) removing the risk factors with patient education about dietary acids and other oral care habits and (2) recommending different toothbrushing and a desensitizing agent for home use. Persistent pains can be treated by (3) applying topical desensitizing agents professionally.[5,6] The treatment mainly focuses on occluding

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the dentinal tubules by various precipitates or covering the exposed dentin with an impermeable layer to prevent the osmotic gradient changes that create the painful stimuli.[19] Most widely available and accepted desensitizer agents are potassium nitrate, potassium or ferric oxalates, and dentin sealers.[20–23]

With the increasing number of adult patients seeking orthodontic treatment, orthodontists may face bonding brackets to hypersensitive teeth treated with desensitizers. The effect of desensitizers on the bond strength of adhesives to dentin is well documented,[24–27] and a consensus has been reached that these agents significantly affected the bond strength. But to our knowledge, the effects of desensitizer agents on shear bond strength of orthodontic adhesives to human enamel were investigated in only two recent studies.[28,29] However, composite specimens were used instead of brackets to test bond strength. The literature still lacks studies investigating the effects of desensitizing agents on bond strengths of orthodontic adhesives to human enamel.

Therefore, the aim of this study was to evaluate the effects of two different kinds of desensitizer agents (potassium nitrate and oxalate) on shear bond strengths of orthodontic brackets.

MATERIALS AND METHODS

Forty-five noncarious, freshly extracted human permanent premolar teeth without any caries or visible defects were stored in 0.1% thymol solution at room temperature. Each tooth was individually embedded in auto polymerizing acrylic resin (Meliodent, Herause Kulzer, Hanau, Germany). The specimens were kept in distilled water except during the bonding and testing procedures. All teeth were randomly assigned to one of three groups of 15 each.

Group I. UltraEZ (Ultradent Products Inc, South Jordan, UT) desensitizer gel was placed in the buccal surfaces of the teeth and left overnight at room temperature. All teeth were rinsed with water before bonding.

Group II. All teeth were etched for 15 seconds and rinsed with water. Then, buccal surfaces were gently dried with moisture-free air spray for 2–3 seconds. BisBlock (Bisco Inc, Schaumburg, IL) was applied, allowed to dwell for 30 seconds, and rinsed. ONE-STEP PLUS (Bisco) was applied and light cured.

Group III. Control group.

Before bonding, the facial surfaces of the teeth were cleaned with a mixture of water and pumice. The teeth were rinsed thoroughly with water and dried with oil and moisture-free compressed air. Each tooth was etched with 37% phosphoric acid gel for 30 seconds. Then, all teeth were rinsed with a water/spray combination for 30 seconds and dried until a characteristic frosty white etched area was observed.

Ormco Mini 2000 (Ormco Corp, Glendora, Calif) bicuspid metal brackets were used. Light Bond (Reliance Orthodontic Products Inc, Itasca, IL) was used as the orthodontic adhesive. With a microbrush, a thin uniform layer of sealant was applied on the etched enamel and cured for 20 seconds. A thin coat of sealant was also painted on the metal bracket base and cured for 10 seconds before applying the paste. The paste was applied to the bracket base using a syringe tip, and the bracket was positioned on the tooth and pressed lightly in the desired position. Excess adhesive was removed with a sharp scaler and cured with Heliolux DLX (Vivadent ETS, Schaan, Liechtenstein) (75W) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surface of the brackets).

All specimens were stored in distilled water at 37°C for 24 hours and thermocycled for 500 cycles between 5°C and 55°C, using a dwell time of 30 seconds. Each specimen was loaded into a universal testing machine (Lloyd; Fareham, Hants, England) using Nexjen software (Nexjen Systems, Charlotte, NC) for testing, with the long axis of the specimen perpendicular to the direction of the applied force. The standard knife edge was positioned in an occlusogingival direction and in contact with the bonded specimen. Bond strength was determined in the shear mode at a crosshead speed of 0.5 mm/min until fracture occurred. The values of failure loads (N) were recorded and converted into megapascals (MPa) by dividing the failure load (N) by the surface area of the bracket base. The bracket base surface area was measured with a digital caliper as 9.63 mm^2.

After debonding, all teeth and brackets in the test groups were examined under 10× magnification. Any adhesive remaining after debonding was assessed and scored according to the modified adhesive remnant index (ARI).[30] The scoring criteria of the index are as follows:

1 = All of the composite, with an impression of the bracket base remained on the tooth
2 = More than 90% of the composite remained on the tooth
3 = More than 10% but less than 90% of the composite remained on the tooth
4 = Less than 10% of composite remained on the tooth
5 = No composite remained on the tooth

Statistical Analysis

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

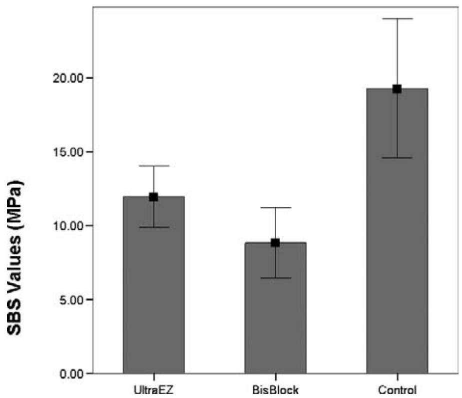

Figure 1. Shear bond strengths (MPa) of the groups.

values were calculated for each of the groups tested. A one-way analysis of variance (ANOVA) and the Tukey multiple comparison tests were used to compare shear bond strengths of the groups. The chi-square test was used to determine any difference in the ARI scores among groups. Significance for all statistical tests was predetermined at $P < .05$. All statistics were performed with SPSS version 13.0.0 (SPSS Inc, Chicago, IL).

RESULTS

The descriptive statistics on the shear bond strength (MPa) for the groups are graphically presented in Figure 1. The minimal bond strength to withstand orthodontic forces is 6–8 MPa.[31] All groups displayed clinically acceptable mean bond strengths (over 8 MPa). ANOVA indicated a significant difference between groups ($P < .001$) (Table 1). The highest shear bond strengths were measured in Group III (control). The shear bond strengths in Groups I and II were significantly lower than in Group III ($P < .001$). Significant difference was also found between Group I and Group II ($P < .01$).

A frequency distribution of the ARI scores and the chi-square comparison of the groups are presented in Table 2. There was a significant difference between groups ($P < .001$). A greater frequency of ARI scores of 4 and 5 in Groups I and II indicated that failures were mainly in the adhesive-tooth interface, whereas scores 1 and 2 were more frequent in Group III, which indicated that failures were mainly in the adhesive-bracket interface.

Table 2. Frequency Distribution of the Adhesive Remnant Index (ARI) Scores and the Chi-Square Comparison of the Groups

	ARI Scores						
Test groups	1	2	3	4	5	n	Test
Group I (UltraEZ)	0	0	0	8	7	15	
Group II (BisBlock)	0	0	0	0	15	15	***
Group III (Control)	3	5	4	1	2	15	

*** $P < .001$.

DISCUSSION

Tooth sensitivity is a common problem that plagues many dental patients. Several desensitizer agents have been used to provide desensitization of the natural teeth. In this study, a potassium nitrate desensitizer gel (UltraEz) and an oxalate desensitizer agent (BisBlock) were used prior to bonding and their effect on the shear bond strengths of orthodontic brackets was compared.

The desensitizing effect of potassium nitrate is believed to result from the sensory nerves being prevented from repolarizing after initial depolarization. Increased levels of potassium nitrate may maintain the depolarized state of the sensory nerves, decreasing the perception of pain.[32,33] Sequential application of these agents resulted in instant occlusion of dentin tubules and immediate relief from the hypersensitivity.

Oxalate desensitizing materials consisting of low concentrations of oxalic acid also work well for desensitization.[34] Application of oxalate materials to the exposed dentin results in precipitation of potassium oxalate or ferric oxalate crystals, occlusion of open tubules in cervical dentin, and instant sclerosis of the tubules.[35] They react with calcium ions on dentin and in dentinal fluid to form insoluble calcium oxalate crystals.[36,37] However, these crystals are either partially dissolved in oral fluids or lost during toothbrushing.[38]

In contrast with other oxalate desensitizers, BisBlock's patented technique is unique because it incorporates the total-etch procedure prior to oxalate and adhesive placement.[22] This technique provides long-lasting effects due to the removal of calcium from the reactive surface and oxalate crystal formation deep within the dentinal tubules as opposed to other techniques utilizing oxalate, which form crystals only on the surface of the tubules. When BisBlock is applied to the root surface, this deposition within the tubules pre-

Table 1. The Results of the Analysis of Variance (ANOVA) Comparing the Shear Bond Strengths of the Groups

Group I (UltraEZ)		Group II (BisBlock)		Group III (Control)			Post-hoc tests		
Mean	SD	Mean	SD	Mean	SD	Significance	I–II	I–III	II–III
11.96	2.07	8.84	2.37	19.29	4.71	.000***	**	***	***

** $P < .01$, *** $P < .001$.

vents dislodgement caused by toothbrush abrasion.[19] However, Pashley et al[39] found that the surface layer of acid-resistant calcium oxalate crystals interfered with resin infiltration through the demineralized collagen matrices, which resulted in poor bonding of total-etch adhesives to oxalate-treated dentin. Pashley et al[39] and Tay et al[22] claimed that when oxalates were used on acid-etched cavities that contain enamel margins, the enamel surfaces became covered by calcium oxalate crystals that could interfere with resin-enamel adhesion. A brief (10–15) second acidic etch could dissolve apatite crystals beneath acid-resistant clinging oxalate crystals and leave etched enamel ready for resin infiltration after the oxalate crystals fall off. However, this should be tested in a laboratory protocol and a clinical trial to verify its effectiveness.

The lowest shear bond strengths obtained in the BisBlock group clearly showed that orthodontic adhesives did not bond well to oxalate-treated enamel. ARI scores of 5 in the BisBlock group indicated that failures were in the adhesive-tooth interface. We think that the surface layer of acid-resistant calcium-oxalate crystals interfered with resin infiltration.

Potassium nitrate gels also affected bonding orthodontic adhesives to enamel. However, the higher shear bond strengths than oxalate-treated specimens indicated that a weaker barrier existed between enamel and adhesive. In contrast with BisBlock's acid-resistant calcium-oxalate crystals, the layer existing after application of potassium nitrate gels is more prone to acid etching.

The results of this in vitro study can be criticized from two points. First, bond strengths obtained in this in vitro study may not correspond well with clinical success. The oral cavity is a complex environment with variations in temperature, stresses, humidity, acidity, and plaque.[40] Although it is impossible to reproduce a laboratory condition which fully represents the oral environment, storage conditions and variations in temperature must at least be similar. Therefore, all specimens were stored and thermocycled as recommended for quality testing of adhesive materials by the International Organization for Standardization in 1993.[41] However, further in vivo studies are still needed to substantiate the results obtained in this in vitro study.

Second, brackets were immediately bonded to the enamel treated with desensitizers. From a clinical perspective, orthodontists do not routinely desensitize teeth. Rather, general dentists do the desensitizing and orthodontists apply the brackets sometime later. Therefore, the time span between desensitizer application and bracket bonding should also be considered as a factor possibly influencing bond strength. This issue will be investigated in a forthcoming project.

CONCLUSIONS

- Orthodontic brackets bonded to enamel treated with potassium nitrate and oxalate desensitizers showed significantly lower bond strengths than brackets bonded to untreated enamel.
- Desensitizer procedures with potassium nitrate and oxalate are not recommended to be done to teeth immediately prior to bonding orthodontic brackets to them.
- Though potassium nitrate and oxalate desensitizers reduce bracket bond strength to enamel, the bond strength with these still exceeds the minimum 6 to 8 MPa required to expect adequate clinical performance.

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