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Comparison of Shear Bond Strengths of Orthodontic Brackets to Enamel using a Self-etching Primer and Phosphoric Acid Etchant Combined with Self-cured and Light-cured Orthodontic Adhesives

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Abstract

The purpose of this study was to compare the shear bond strengths of orthodontic brackets bonded to enamel surfaces using a self-etching primer system and phosphoric acid etching technique with self-cured (Unite™, 3M Unitek) and light-cured adhesives (Transbond™ XT, 3M Unitek). The metal orthodontic brackets were bonded under different enamel surface preparations: Group 1 (n = 20): 37% phosphoric acid etching, bonded with Unite™; Group 2 (n = 20): 37% phosphoric acid etching, bonded with Transbond™ XT; Group 3 (n = 20): self-etching primer, bonded with Unite™; Group 4 (n = 20): self-etching primer, bonded with Transbond™ XT. All specimens were stored in distilled water at 37°C for 24 hours and then thermocycled between 4°C and 55°C for 1000 cycles before debonding. An Instron universal testing machine was used to determine the shear bond strength at a crosshead speed of 0.5 mm/min. Mean shear bond strength of group 1 2 and 4 were significantly greater than group 3, but there were no statistical differences ($p > .05$) among group 1 2 and 4. It can be concluded that the mean shear bond strength of groups 1 2 and 4 are clinically acceptable. However, group 3 has the lowest bond strength compared to group 1 2 and 4 and may not be clinically acceptable.

Key words: acid etch; light-cured; orthodontic adhesives; self-cured; self-etching primer; shear bond strength

Introduction

In orthodontic practice, it is essential to obtain a reliable adhesive bond between an orthodontic attachment and enamel tooth surface. Traditionally, direct bonding of orthodontic brackets can be achieved by etching the enamel surface with 37% phosphoric acid; the etched surface is then rinsed and dried, prior to application of primer and adhesive to complete the process. The disadvantages of this conventional technique are the loss of enamel during etching, the necessity of dry field operation and the required multiple steps.[1]

To simplify clinical orthodontic bonding procedures and to decrease chairside time and technique sensitivity, the new Transbond™ Plus Self Etching Primer or 'SEP' (3M Unitek, Monrovia, California, USA) has been introduced. A unique characteristic of SEP system is the combination of acid etching, rinsing and priming steps. It allows simultaneous acid etching and primer infiltration, without the need for subsequent rinsing. After applying SEP, only a burst of air on the tooth surface is required before placing a bracket. Chairside time is reduced with this system.

Previous studies on the shear bond strength of orthodontic brackets using SEP have shown varying results. Bishara et al[2] and Aljubouri's et al[3] reported that the shear bond strength obtained with an acidic primer were less than that with the 37% phosphoric acid etching technique and might not be clinically reliable. However, in recent studies, Bishara et al[4] suggested that although the mean shear bond strength from the SEP system was significantly less than that obtained by the 37% phosphoric acid etching technique, it could be clinically acceptable. On the contrary, Grubisa et al[5] showed that the mean shear bond strengths of the two techniques were not significantly different. Most studies have been limited to the evaluation of the shear bond strengths of light-cured orthodontic adhesives applied with SEP. There has been no report about the shear bond strength of self-cured orthodontic adhesive resins using the new SEP system.

The purpose of this study was to compare the mean shear bond strengths of orthodontic brackets to enamel surfaces using a new self-etching primer and the phosphoric acid etchant with self-cured and light-cured orthodontic adhesives.

Materials and Methods

Eighty extracted human premolars were collected and stored in distilled water mixed with thymol crystals to inhibit bacterial growth. Exclusion criteria for the collected premolars included the presence of restorations, enamel defects and abnormal cracking. The teeth were randomly divided into four groups of 20 teeth. The teeth were mounted in acrylic within polyvinyl chloride (PVC) rings.

The etchant and adhesive bonding materials used in the procedure are shown in Table 1. 37% phosphoric acid etchant and Transbond™Plus Self Etching Primer (SEP) (3M Unitek, Monrovia, California, USA) were used to prepare tooth surfaces prior to bonding orthodontic brackets to enamel. Unitek™ Miniature Twin Metal Bracket (3M Unitek, Monrovia, California, USA) with micro-etched base type and an average bracket base area of 9 mm^2 (3x3 mm) for maxillary premolar teeth were used to bond to all teeth using either Unite™ Bonding Adhesive (3M Unitek, Monrovia, California, USA) or Transbond™XT Light Cure Orthodontic Adhesive (3M Unitek, Monrovia, California, USA).

Table 1 *Materials used in this study*

Agent	Composition	Manufacturer
Etchant Total-etch	37% Phosphoric acid	3M ESPE
Transbond™Plus Self Etching primer	Methacrylated phosphoric acid ester	3M Unitek Co.
Orthodontic adhesive Transbond™XT	BisGMA/BisEMA, Fillers, Camphoroquinone Triethylene Glycol Dimethacrylate, Bisphenol A Diglycidyl Ether Dimethacrylate	3M Unitek Co.
Unite™	BisGMA/TEGDMA, Fillers Triethylene Glycol Dimethacrylate, Bisphenol A Diglycidyl Ether Dimethacrylate, 2,2'-(P-Tolylimino) Diethanol, Poly(Methyl Methacrylate), Methacryloxypropyltrimethoxysilane	3M Unitek Co.

Bonding Protocol

The tooth surfaces were cleaned with pumice, rinsed and dried by air blow from triple syringe. The teeth were bonded using the following bonding techniques:

Group 1: 37% Phosphoric acid+Unite™ (Etch+Unite™): The enamel was etched with 37% phosphoric acid gel for 20 seconds followed by thorough washing and drying. The Unite™ primer was applied on the etched enamel surface and the bracket base and the brackets were then bonded using Unite™ adhesive.

Group 2: 37% Phosphoric acid+Transbond™XT (Etch+ Transbond™XT): The enamel was etched with 37% phosphoric acid gel for 20 seconds followed by thorough washing and drying. The Transbond™XT primer was applied on the etched enamel surface and the bracket base and the brackets were then bonded using Transbond™XT adhesive and light-cured for 40 seconds (20 seconds on the mesial and 20 seconds on the distal wings of the bracket).

Group 3: SEP+Unite™: SEP was applied in a circular motion on the enamel surface for 3 seconds and an air burst was applied for 5 seconds. The Unite™ primer was applied only on the bracket base and the brackets were then bonded using Unite™ adhesive.

Group 4: SEP+Transbond™XT: SEP was applied in a circular motion on the enamel surface for 3 seconds and an air burst was applied for 5 seconds. The Transbond™XT primer was applied only on the bracket base and the brackets were then bonded using Transbond™XT adhesive and light-cured for 40 seconds (20 seconds on the mesial and 20 seconds on the distal wings of the bracket).

All samples were stored in distilled water at 37°C for 24 hours and then thermocycled between 4°C and 55°C, with a 30-second interval between cycle, for 24 hours.

Debonding protocol

The brackets were debonded with a shear-peel force exerted parallel to the bracket base using a universal testing machine (Instron, Canton, Massachusette, USA) in an occluso-gingival direction at a crosshead speed of 0.5 mm/minute.

Statistical Analysis

Descriptive statistical analyses, including mean, standard deviation, standard error, minimum and maximum values were calculated for each of the four groups tested. Differences between the groups were then evaluated by a one-way analysis of variance (ANOVA). If a significant difference was found, the Scheffe′ test was used to identify which of the groups were different. Significance for all statistical tests was predetermined at $p < .05$.

Results

The mean shear bond strength of all experiment teeth are presented in the Table 2. The results of the one-way analysis of variance (ANOVA) and Scheffé test indicated that the mean shear bond strengths among three groups: Group 1 2 and 4 were not significantly different ($p < .05$). The mean shear bond strength of group 3 was significantly lower than that of other groups.

Table 2 *Descriptive statistics and results of the analysis of variance comparing the shear bond strength in MPa of the four groups evaluated*

Groups tested	N	Mean SBS (MPa)	S.D.	S.E.	95% Confidence interval of mean	
					lower	upper
Gr 1 Etch+Unite™	20	8.97	4.0	.89	7.09	10.85
Gr 2 Etch+Transbond™XT	20	9.96	2.9	.64	8.61	11.32
Gr 3 SEP+Unite™	20	2.07	1.5	.33	1.38	2.77
Gr 4 SEP+Transbond™XT	20	7.55	3.2	.71	6.05	9.04

Discussion

The mean shear bond strengths in this study were comparable to those earlier reported by Bishara et al[2,4] and Arnold[6] except that of Group 3 (SEP+Unite™). Reynolds[7] stated that 5-8 MPa is the minimum shear bond strength requirement for an orthodontic bracket attached to enamel. Thus, the mean bond strengths of Group 1 (Etch+Unite™), Group 2 (Etch+Transbond™XT) and Group 4 (SEP+Transbond™XT) were clinically acceptable.

The application of phosphoric acid on the enamel surface transforms it to high surface energy with microporosity. The resin can then penetrate into the micropores and form a mechanical bond to the treated enamel surface.[8] In common procedures, etching, cleaning, and drying of the enamel are required prior to bracket bonding. But, with SEP, the mechanical bond between the bracket and the tooth surface is acquired differently. The phosphate group of the methacrylated phosphoric acid ester dissolves calcium and removes it from hydroxyapatite. Rather than being rinsed away, calcium forms a complex with the phosphate group when the primer molecules are polymerized and is incorporated into the network structure. Enamel etching and primer penetration into the exposed enamel rods are simultaneous. The depth of the etched enamel and the primer penetration are identical.[9]

Etching patterns of aprismatic enamel varied accordingly to the aggressiveness of different self-etching primers but they are similar to those obtained with phosphoric acid etchant.[10,11] However, SEP produces less depth of enamel surface penetration.[10,11] This may be one of the reasons why slightly lower bond strengths was achieved in Group 4 (SEP+Transbond™XT), compared to Group 2 (Etch+Transbond™XT), but they were not statistically significantly different.

The substantially low bond strength was found in teeth bonded with SEP and self-cured adhesive (2.07 MPa). This value was statistically different from other groups and is not strong enough to withstand masticatory forces. Proper environment is needed to complete polymerization of self-cured adhesive systems. The residual acidity of the SEP on the enamel surface may result in incomplete polymerization of the chemical-cured adhesive, which causes low bond strength.[12]

After tooth surface preparation using phosphoric acid etchant or SEP, the primer is applied to enamel surface and the bracket base. Either a self-cured or a light-cured adhesive paste is placed under the bracket base and the bracket must be pressed against the enamel surface to complete polymerization with or without light activation for self-cured adhesive. As mentioned earlier, the shear bond strength obtained when using SEP combination with light-cured adhesive was lower than that using phosphoric acid etching technique. But, its less technique sensitivity and less chair time may be beneficial to patients and orthodontists. Further researches are required to test the shear bond strength of the SEP systems over a longer period of time.

Conclusion

It can be concluded that there was no significant difference in shear bond strengths of orthodontic brackets to enamel surfaces, whether 37% phosphoric acid etchant or a self-etching primer was used with a light-cured adhesive, and also when 37% phosphoric acid etching was used with a self-cured adhesive. However, it seemed that the self-etching primer was incompatible with the self-cured adhesive since its bond strength was substantially low.

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การเปรียบเทียบค่าแรงเฉือนของแบร็กเกตจัดฟันกับผิวเคลือบฟันเมื่อใช้กรดกัดผิวฟันชนิดเซลฟ์เอตช์และกรดกัดผิวฟันฟอสฟอริคร่วมกับวัสดุยึดติดทางทันตกรรมจัดฟันชนิดบ่มด้วยตนเองและชนิดฉายแสง

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บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อเปรียบเทียบค่าแรงเฉือนของแบร็กเกตจัดฟันกับผิวเคลือบฟันโดยการใช้กรดกัดผิวฟันชนิดเซลฟ์เอตช์และกรดฟอสฟอริคร่วมกับวัสดุยึดติดชนิดบ่มด้วยตนเอง (ยูไนต์ สามเอ็มยูนิเทค) และ ชนิดฉายแสง (ทรานส์บอนด์เอกซ์ทีสามเอ็มยูนิเทค) แบร็คเก็ตจัดฟันชนิดโลหะถูกยึดติดบนผิวฟันที่ถูกเตรียมด้วยวิธีต่าง ๆ ดังนี้ กลุ่มตัวอย่างที่ 1 (จำนวน 20 ซี่) เตรียมผิวฟันโดยใช้กรดฟอสฟอริกความเข้มข้น 37% ยึดติดแบร็กเกตโดยใช้ยูไนต์ กลุ่มตัวอย่างที่ 2 (จำนวน 20 ซี่) เตรียมผิวฟันโดยใช้กรดฟอสฟอริก 37% ยึดติดแบร็กเกตโดยใช้ทรานส์บอนด์เอกซ์ที กลุ่มตัวอย่างที่ 3 (จำนวน 20 ซี่) เตรียมผิวฟันโดยใช้สารยึดติดชนิดเซลฟ์เอตช์ ยึดติดแบร็กเกตโดยใช้ยูไนต์ กลุ่มตัวอย่างที่ 4 (จำนวน 20 ซี่) เตรียมผิวฟันโดยใช้สารยึดติดชนิดเซลฟ์เอตช์ยึดติดแบร็กเกตโดยใช้ทรานส์บอนด์เอกซ์ที กลุ่มตัวอย่างทั้งหมดถูกนำไปแช่ไว้ในน้ำกลั่นที่อุณหภูมิ 37 องศาเซลเซียส เป็นเวลา 24 ชั่วโมงหลังจากนั้นนำไปผ่านขบวนการจำลองการเปลี่ยนแปลงสภาวะความแตกต่างของอุณหภูมิ ระหว่างอุณหภูมิ 4 และ 55 องศาเซลเซียส จำนวน 1,000 รอบ แล้วจึงนำไปทดสอบค่าแรงเฉือนของการยึดติดโดยใช้เครื่องทดสอบอินสตรอน วัดค่าแรงเฉือน ที่ความเร็ว 0.5 มม./นาที ผลการวิเคราะห์ พบว่า ค่าแรงเฉือนเฉลี่ยของกลุ่มตัวอย่างที่ 1 ที่ 2 และ ที่ 4 สูงกว่ากลุ่มตัวอย่างที่ 3 อย่างมีนัยสำคัญทางสถิติ ($p < .05$) แต่ค่าแรงเฉือนเฉลี่ยของกลุ่มตัวอย่างที่ 1 ที่ 2 และ ที่ 4 ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ สรุปได้ว่า กลุ่มที่ 1 ที่ 2 และ ที่ 4 ให้ค่าแรงเฉือนเฉลี่ยเป็นที่ยอมรับให้ใช้ได้ในทางคลินิก แต่กลุ่มที่ 3 มีค่าแรงเฉือนเฉลี่ยต่ำที่สุดในกลุ่มตัวอย่างทั้ง 4 และอาจไม่เป็นที่ยอมรับให้ใช้ได้ในทางคลินิก