กำลังยึดติดแบบเฉือนของระบบยึดติดชนิดการกัดด้วยกรดในตัวเองแบบ 1 ขั้นตอนและแบบ 2 ขั้นตอน สำหรับการยึดแบร็กเกตเซรามิค

Shear Bond Strength of One-Step and Two-Step Self-Etching Adhesive Systems for Bonding Ceramic Brackets

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บทคัดย่อ

วัตถุประสงค์ของการศึกษานี้เพื่อเปรียบเทียบค่าเฉลี่ยกำลังยึดติดแบบเฉือนของระบบยึดติดชนิดการกัดด้วยกรดแบบสัญนิยม การกัดด้วยกรดในตัวเองแบบ 1 ขั้นตอนและแบบ 2 ขั้นตอน สำหรับการยึดแบร็กเกตเซรามิค นำฟันกรามน้อยบนซี่ที่หนึ่งจำนวน 60 ซี่ มาสุ่มและแบ่งเป็นสามกลุ่ม ยึดแบร็กเกตเซรามิคบนฟันแต่ละซี่โดยใช้ระบบยึดติดหนึ่งในสามชนิดที่ใช้ในการทดลอง วัดค่าเฉลี่ยกำลังยึดติดแบบเฉือนโดยใช้เครื่องทดสอบแรงแบบสากลที่ความเร็วหัวกด 0.5 มิลลิเมตรต่อนาที ผลการวิเคราะห์ความแปรปรวน

Abstract

The objective of this study was to compare the mean shear bond strength values among total-etching, two-step and one-step self-etching adhesive systems for bonding ceramic brackets. Sixty upper first premolars were randomized and categorized into three groups, in each of which the teeth were bonded to ceramic brackets using one of the adhesive systems. Mean shear bond strength values were measured by using an universal testing machine at a crosshead speed of

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แบบทางเดียวพบว่า ค่าเฉลี่ยกำลังยึดติดแบบเฉือนของระบบการยึดติดชนิดการกัดด้วยกรดในตัวเอง แบบ 2 ขั้นตอนและแบบ 1 ขั้นตอนมีค่าน้อยกว่าระบบการกัดด้วยกรดแบบสัญนิยมอย่างมีนัยสำคัญทางสถิติที่ ($p<0.05$) แต่ค่าเฉลี่ยกำลังยึดติดแบบเฉือนของระบบการกัดด้วยกรดในตัวเอง แบบ 2 ขั้นตอนและแบบ 1 ขั้น ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ

คำสำคัญ: แบร็กเกตเซรามิค ระบบการยึดติดชนิดการกัดด้วยกรดแบบสัญนิยม ระบบการยึดติดชนิดการกัดด้วยกรดในตัวเอง กำลังยึดติดแบบเฉือน

0.5 millimeters per minute. The results of one-way ANOVA indicated that the mean shear bond strength values of the two-step and one-step adhesive systems were significantly lower than those of the total-etching adhesive system ($p< 0.05$). However, there was no significant difference between the two-step and one-step adhesive systems.

Keywords: Ceramic Brackets, Total-Etching Adhesive System, Self-Etching Adhesive System, Shear Bond Strength

Introduction

Initially, orthodontic brackets or attachments were welded to metal bands. In restorative dentistry, Bounocore,[1] in 1955, introduced an enamel acid-etching technique, using 85% phosphoric acid, to increase the retention of acrylic resin to the enamel surface. This technique was adopted in orthodontics for bracket bonding. However, the disadvantages of total-etching adhesive systems are as follows: long operating time, risk of saliva contamination and inconvenience of patient and operator.[2,3] In 1989, self-etching adhesive systems were developed as a two-step self-etching adhesive systems by combining etchant and primer.[4] Recently, manufacturers have attempted to combine etchant, primer and bonding resin into a single solution (all-in-one adhesives), rendering the systems one-step self-etching adhesive systems.[5] These systems reduce bonding time, eliminate the rinsing step and allow easy moisture control.[6]

There is controversy regarding the use of self-etching adhesive systems. Yamada et al.[7] found that the shear bond strength values of brackets bonded using a self-etching adhesive system were significantly lower than for those bonded using a total-etching adhesive system. However, many researchers have reported no significant difference.[8-14] Attar et al.[15] reported that the shear bond strength of orthodontic brackets bonded by using one-step, two-step self-etching or total-etching adhesive systems were not significantly different, whereas others[16,17] have shown that the shear bond strength of one-step self-etching adhesive systems was not significantly different from that of two-step self-etching adhesive systems.

Originally, brackets were made of metal. The disadvantages of metal brackets are lack of aesthetics and long curing time when bonded with light-cured adhesive systems.[18] Most patients search for esthetics during treatment, so the ceramic bracket system was later introduced.[19,20] Ceramic brackets are transparent and color stable, strong, difficult to deform, resistant to compressive strengths, and require less curing time than metal brackets do.[21,22]

The use of a one-step self-etching adhesive system combined with ceramic brackets may provide less operating time than do those with a greater number of steps by reducing the intermediate steps in the bonding procedure, increase

cost effectiveness and maximize esthetics for patient satisfaction. So, the purposes of this study were to compare mean shear bond strength values of a total-etching adhesive system, a two-step and a one-step self- etching adhesive system for bonding ceramic brackets, and to evaluate adhesive remnant index (ARI) scores on tooth surfaces after de-bonding.

Materials and methods

Sixty maxillary first premolar teeth, extracted for orthodontic treatment purposes, were collected and stored in 0.1% thymol solution at room temperature (25°C). The teeth were used within 6 months after extraction. Selection criteria were as follows: intact surface, free from caries, no dental fluorosis, no restorations or cracks on the labial surface, and no contamination by any chemical agents. The buccal surface of each tooth was cleaned and polished with fluoride-free pumice using a low-speed handpiece for 10 seconds, rinsed with water for 10 seconds, and dried with oil-free air for 10 seconds. Sixty premolar teeth were randomly divided into three groups of 20 teeth for bonding with each type of three adhesive systems: Group1) a total-etching adhesive system (37% phosphoric acid, Ormco, Glendora, California, USA and Transbond XT™ primer (3M Unitek, Monrovia, California, USA), Group 2) a two-step self-etching adhesive system (Clearfil SE bond, Kuraray Medical, Osaka, Japan) and Group 3) a one-step self-etching adhesive system (Clearfil S^3 bond, Kuraray Medical). Each tooth was used with Transbond XT™ paste (3M Unitek).

The compositions of the adhesive systems used in this study are listed in Table 1.

Sixty maxillary premolar ceramic brackets (Clarity™, 3M Unitek, California, USA) were used in the present study. The average surface area of the Clarity™ bracket base was 10.59 square millimeters.[23]

Three bonding procedures were used, one for each group. All brackets were bonded to the buccal surfaces of maxillary premolar teeth. The vertical axis of the bracket was parallel to long axis of the tooth, and the slot of the bracket was at the center of the long axis of the clinical crown. Brackets in all groups were bonded as recommended by the manufacturer' s directions.

Group 1 (Total-etching adhesive system)

In the first step, buccal tooth surfaces were etched with 37% phosphoric acid solution for 30 seconds, rinsed with water for 15 seconds, and dried with light oil-free compressed air until a frosted enamel appearance was achieved. In the second step, Transbond XT™ primer was applied onto the etched surface with a micro-brush and cured for 10 seconds. In the third step, Transbond XT™ paste was applied on the bracket base. The brackets were placed with firm pressure. The excess resin composite was removed with an explorer. In the fourth step, a mini-LED™ (Satelec® Acteon, Merignac, France) was used to cure the adhesive at the midbracket position for 5 seconds. The distance between the light tip of the mini-LED™ and the midbracket area was 2 mm.

Group 2 (Two-step self-etching adhesive system)

Clearfil SE primer, which includes etchant and primer together was first applied to the buccal tooth surfaces by agitation with a micro-brush for 5 seconds, and the surfaces were lightly dried with oil-free compressed air. Then, bonding agent was applied, dried gently and light-cured with the mini-LED™ for 10 seconds. Transbond XT™ paste was then applied on the bracket bases. The brackets were placed and cured as described for Group 1.

Table 1 *Compositions of Transbond XT™, Clearfil SE bond and Clearfil S³ Bond.*
ตารางที่ 1 *ส่วนประกอบของทรานส์บอนด์ เอกซ์ที เคลียร์ฟิลเอสอีบอนด์และเคลียร์ฟิลไตรเอสบอนด์*

Adhesives	Composition	Type
Etchant (Ormco, USA) and Transbond XT™ (3M Unitek, Monrovia CA, USA)	Etching : 37%Phosphoric acid Primer : TEGDMA, Bis-GMA Paste : Bis-GMA, TEGDMA, silane-treated quartz, amorphous silica, camphorquinone	Total-etching
Clearfil SE Bond (Kuraray, Japan) \	Primer: 10-MDP, HEMA, hydrophilic DMA, tertiary amine, water, photo-initiator Bonding: 10-MDP, HEMA, bis-GMA, hydrophilic DMA, tertiary amine, silanated, colloidal silica, photo-initiator (Filler : Silinatecolloidal Solvent : no, pH = 1.8)	Two-step self-etching
Clearfil S³ Bond (Kuraray, Japan)	10-MDP, HEMA, bis-GMA, water, ethanol, silanated colloidal silica, camphorquinone (Filler : Colloidal silica, Solvent : Ethyl alcohol, pH= 1)	One-step self-etching

Abbreviations: bis-GMA, bisphenol glycidyl methacrylate; DMA, dimethacrylate; HEMA, 2-hydroxyethyl methacrylate; 10-MDP, 10- methacryloyloxy decyl dihydrogenphosphate.

Group 3 (One-step self-etching adhesive system)

Clearfil S³ Bond, containing etchant, primer and bonding agent in a single solution, was applied to the buccal tooth surfaces by agitation with a micro-brush for 5 seconds, the surfaces were dried using high-pressure oil-free compressed air and the adhesive was light-cured with the mini-LED™ for 10 seconds. Transbond XT™ paste was then applied on the bracket bases. The brackets were placed and cured as described for Group 1.

All bonded specimens were embedded in a self-cured acrylic resin in stainless steel rings (Figure 1) and submerged in distilled water at 37±1°C for 24 hours. After storage, all specimens were subjected for thermocycling in water baths at 5°C and 55°C for 1,000 cycles. The exposure to each bath was 30 seconds, and the transfer time between the two baths was 10 seconds. Shear bond strength was tested by using a universal testing machine with a 500 Newtons load cell (Instron Calibration Laboratory, Norwood,

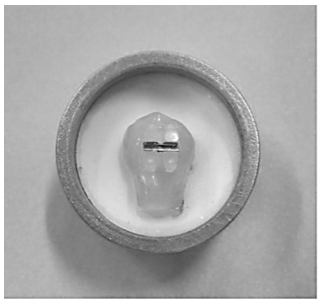

Figure 1 *Specimen embedded in self-cured acrylic resin in stainless steel ring.*

รูปที่ 1 *การฝังชิ้นตัวอย่างในวงแหวนโลหะปลอดสนิมด้วยอะคริลิกเรซินชนิดบ่มเอง*

Massachusetts, USA). The cross head speed was 0.5 mm/minute. De-bonding force was applied in a gingivo-occlusal direction between the enamel surface and the bracket base until the bracket dislodged from the tooth surface (Figure 2). The force was directly recorded in Newtons and converted into megapascals (MPa) by the attached computer.

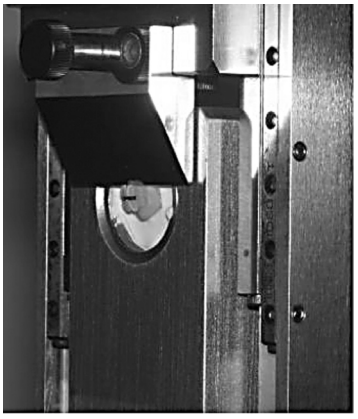

Figure 2 *The force from an universal testing machine was applied between the enamel surface and the bracket base.*

รูปที่ 2 *เครื่องทดสอบสากลให้แรงระหว่างผิวเคลือบฟันกับฐานแบร็กเกต*

After de-bonding of brackets, bracket base images were recorded using a digital single-lens reflex camera (Canon Kiss x, Japan) at 1x magnification to assess the amounts of residual adhesives on the de-bonded bracket bases. The percentages of residual adhesives on the bracket base were calculated and converted to percentages of residual adhesives on the enamel surface. The amounts of residual adhesives were scored by using the Adhesive Remnant Index (ARI score) as follows.[24]

Score ‘ 0’ = No adhesive left on the tooth

Score ‘ 1’ = Less than half of the adhesive left on the tooth

Score ‘ 2’ = More than half of the adhesive left on the tooth

Score ‘ 3’ = All of the adhesive left on the tooth

Descriptive statistics, including the mean, standard deviation, minimum and maximum values, were calculated for each group. The results of the mean shear bond strength values were analyzed by One-way analysis of variance and the Post Hoc Tukey HSD test. The Adhesive Remnant Index scores were analyzed by the Chi-square test. Significance was determined at $p<0.05$.

Results

The statistics describing the shear bond strength values of orthodontic ceramic brackets bonded to teeth with the total-etching adhesive system, the two-step and the one-step self-etching adhesive systems are shown in Table 2.

The results of one-way ANOVA indicate that the mean shear bond strength values of the total-etching adhesive system, the two-step and the one-step self-etching adhesive systems were significantly different at $p = 0.000$.

The Post Hoc Tukey HSD test was used to determine the statistical differences in mean shear bond strength values between adhesive systems. There were statistically significant differences at $p=0.000$ between the total-etching adhesive system and the two-step self-etching adhesive system, and

Table 2 *Means, standard deviations and ranges of shear bond strength values of total-etching, two-step self-etching and one-step self-etching adhesive systems with ceramic brackets.*

ตารางที่ 2 *ค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน และพิสัย ของค่ากำลังยึดติดแบบเฉือนของระบบยึดติดชนิดการกัดด้วยกรดสัญนิยม การกัดด้วยกรดในตัวเองแบบ 2 ขั้นตอน และแบบ 1 ขั้นตอน สำหรับการยึดแบร็กเกตเซรามิค*

Group	Adhesive systems	Shear Bond Strength (MPa)			
		Mean	SD	Min	Max
1	37%Phosphoric acid with Transbond XT™	8.65*, **	1.41	4.43	9.92
2	Clearfil SE bond	7.06*	1.80	3.82	9.90
3	Clearfil S^3 bond	6.35**	2.24	2.26	9.86

**indicates significant difference at p = 0.05 between Groups 1 and 2.*

***indicates significant difference at p = 0.05 between Groups 1 and 3.*

between the total-etching adhesive system and the one-step self-etching adhesive system. There were no statistically significant differences between the two-step self-etching adhesive system and the one-step self-etching adhesive system at $p = 0.616$.

The frequency distributions of Adhesive Remnant Index scores for each group are shown in Table 3. The results of Chi-square test indicate that there had relationship between Adhesive Remnant Index and adhesive systems at $p<0.05$. The total-etching adhesive system (Group 1) left more adhesive on the enamel surfaces than any of the other adhesive systems did. The self-etching adhesive systems left more adhesive on the bracket bases than the total-etching system did.

Discussion

Originally, self-etching adhesive systems were introduced for use in operative dentistry. Subsequently, self-etching adhesive systems were also used in orthodontic bonding. However, there is some controversy regarding the bond strength of self-etching adhesive systems.[2,5-9]

Our results indicated that the mean shear bond strength value of a total-etching adhesive system was significantly higher than those of a two-step and a one-step self-etching system. However, the mean shear bond strength value of the two-step self-etching adhesive system was not significantly different from those of the one-step self-etching adhesive system. The higher shear bond strength of the total-etching adhesive system can be explained by the fact that etching with 37% phosphoric acid in the total-etching adhesive systems dissolves deeply hydroxyapatite crystals and permits a depth of resin infiltration into enamel.[25] Self-etching adhesive systems have less etching ability than total-etching adhesive systems do because of high pH.[26] The degree of penetration by self-etching adhesive systems is less than that by total-etching adhesive systems.[15] One-step and two-step self-etching adhesive systems provide relatively low bond strength values in comparison to those provided by total-etching adhesive systems. Because self-etching adhesive systems are high hydrophilic, water is absorbed through the adhesive layer, which acts as a permeable membrane.[27,28] However, shear bond strength values of one-step self-etching adhesive systems are the same as those of two-step self-etching adhesive systems.

The requirements for orthodontic bonding systems are resistance to forces during orthodontic mechanotherapy, stresses exerted by the archwires, forces of mastication, and patient abuse, as well as control of tooth movement in all three planes of

Table 3 *Frequency distributions of the Adhesive Remnant Index scores of each group.*
ตารางที่ 3 *การกระจายความถี่ของดัชนีเอ อาร์ ไอ ในแต่ละกลุ่ม*

Group	Adhesive system	ARI scores				
		n	0	1	2	3
1	37% Phosphoric acid with Transbond XT™	20	0 (0%)	2 (10%)	0 (0%)	18 (90%)
2	Clearfil SE bond	20	7 (35%)	7 (35%)	3 (15%)	3 (15%)
3	Clearfil S^3 bond	20	4 (20%)	12 (60%)	3 (15%)	1 (5%)

ARI scores : 0, no adhesive left on tooth; 1, less than half of adhesive left on tooth; 2, more than half of adhesive left on tooth; 3, all adhesive left on tooth with a distinct impression of the bracket.

space.[29] However, excessively high bond strength values are undesirable because of the increased de-bonding forces needed, resulting in possible damage to enamel.[30] Reynolds and Von Fraunhofer[31] suggested bond strength values from 6 to 8 MPa as being adequate for clinical uses. Retief[32] demonstrated that maximum bond strength of an orthodontic bracket should be less than the breaking strength of enamel, which is about 14 MPa. In this present study, the highest bond strength value of the total-etching adhesive system was 9.92 MPa and the bond strength values in all groups were less than 14 MPa. Furthermore, no enamel fracture was detected in any group in this study.

This present study indicated more residual adhesive on enamel surfaces bonded with the total-etching adhesive system than on those bonded with the self-etching adhesive systems, similar to the findings of previous studies.[33-35] This may be indicative of a reduced etch pattern and of reduction in the quality of the micromechanical bond of self-etching adhesive systems.[36] The residual adhesive on bracket bases bonded with two-step and one-step self-etching adhesive systems is advantageous, because it reduces chair time to remove the residual adhesive. However, the enamel surface can be damaged when brackets fail at the enamel/adhesive interface.[37]

Further studies should evaluate the enamel etching pattern of two-step self-etching adhesive systems and of one-step self-etching adhesive systems using scanning electron microscopy prior to bonding brackets to enamel surfaces.

Conclusions

1. The mean shear bond strength values of a two-step self-etching adhesive system and a one-step self-etching adhesive system were significantly lower than those of a total-etching adhesive system for bonding ceramic brackets ($p< 0.05$). However, the mean shear bond strength values of the two-step self-etching adhesive system were not significantly different from those of the one-step self-etching adhesive system.

2. The one-step and two-step self-etching adhesive systems left less adhesive remaining on tooth surfaces after de-bonding than the total-etching adhesive system did.

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