พลของสารยึดติดแบบเปลี่ยนสีและความเร็วของหัวกรอภายหลังการถอดแบร็กเกต: การศึกษาแบบ 3 มิติ

Effects of Color-change Adhesive and Handpiece Speed after Bracket Debonding: A 3-dimensional Study

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ชม. ทันตสาร 2563; 41(3) : 43-54
CM Dent J 2020; 41(3) : 43-54

Received: 5 June, 2019
Revised: 31 July, 2019
Accepted: 26 August, 2019

บทคัดย่อ

วัตถุประสงค์: เพื่อประเมินและเปรียบเทียบสารยึดติดส่วนเหลือ การสูญเสียเคลือบฟันจากการใช้สารยึดติดแบบเปลี่ยนสีกับแบบสัญนิยมและการกรอสารยึดออกด้วยด้ามกรอความเร็วต่ำกับด้ามกรอความเร็วสูง

วัสดุและวิธีการ: สแกนฟันกรามน้อยบน 80 ซี่ด้วยเครื่องสแกน 3 มิติเป็นภาพสแกนแรก ติดแบร็กเกตที่ฟัน 40 ซี่แรกด้วยสารยึดติดแบบเปลี่ยนสี (ชนิด CCA) และ 40 ซี่หลังด้วยสารยึดติดแบบสัญนิยม (ชนิด CLA) ทิ้งไว้ 24 ชั่วโมงจึงถอดแบร็กเกตออก สแกนฟันทุกซี่เป็นภาพสแกนหลังถอดแบร็กเกต แบ่งกลุ่มตัวอย่างชนิด CCA แบบสุ่มเป็น 2 กลุ่มประกอบด้วยกลุ่ม CCL และ CCH จำนวน 21 และ 19 ซี่ ตามลำดับ แบ่งกลุ่มตัวอย่างชนิด CLA แบบสุ่มเป็น 2 กลุ่มประกอบด้วยกลุ่ม CLL และ CLH จำนวน

Abstract

Objective: To assess and compare adhesive remnants, enamel loss of color-change adhesive to conventional light-cured adhesive after bracket debonding and adhesive removal with low and high speed handpiece.

Materials and Methods: Eighty extracted maxillary premolars were scanned with a 3D optical scanner. 40 were bracket-bonded with color-change adhesive (CCA type) while 40 with conventional light-cured adhesive (CLA type). Brackets were debonded 24 hours after bonding. All teeth were scanned (after-debonding scan). Samples of CCA type were divided into 2 groups randomly:

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อย่างละ 20 ซี่ กรอสารยึดติดส่วนเหลือของกลุ่ม CCL และ CLL ด้วยหัวกรอคาร์ไบด์ร่วมกับด้ามกรอความเร็วต่ำ ส่วนกลุ่ม CCH และ CLH กรอด้วยด้ามกรอความเร็วสูง บันทึกเวลาที่ใช้ในการกรอและสแกนฟันเป็นภาพสแกนหลังกรอสารยึดติด นำภาพสแกนหลังถอดแบร็กเกต ภาพสแกนหลังกรอสารยึดติดซ้อนทับกันภาพสแกนแรก เพื่อคำนวณพื้นผิวที่เปลี่ยนแปลง วิเคราะห์ทางสถิติด้วยการทดสอบครัสคัลวอลลิส (α =0.05)

ผลการศึกษา: พื้นที่และปริมาตรของสารยึดติดหลังถอดแบร็กเกตชนิด CCA มีค่าน้อยกว่าชนิด CLA อย่างมีนัยสำคัญทางสถิติ การกรอสารยึดติดชนิด CCA พบว่าความหนาและปริมาตรของเคลือบฟันสูญเสียไปน้อยกว่าชนิด CLA แต่ไม่มีนัยสำคัญ ส่วนการกรอด้วยด้ามกรอความเร็วต่ำสูญเสียความหนาของเคลือบฟันน้อยกว่าด้ามกรอความเร็วสูงอย่างมีนัยสำคัญและสูญเสียปริมาตรของเคลือบฟันน้อยกว่าแต่ไม่มีนัยสำคัญ สารยึดติดตกค้างภายหลังการกรอสารยึดติดชนิด CCA น้อยกว่าชนิด CLA อย่างมีนัยสำคัญยกเว้นกลุ่ม CCH และ CLH ที่ไม่แตกต่างกัน การกรอสารยึดติดชนิด CLA ด้วยด้ามกรอความเร็วต่ำจะมีสารยึดติดตกค้างมากกว่าการกรอด้วยด้ามกรอความเร็วสูงทั้งความหนาและปริมาตร กลุ่ม CCA ใช้เวลาในกรอสารยึดออกน้อยที่สุด ตามด้วยกลุ่ม CLH CCL และ CLL ที่แตกต่างอย่างมีนัยสำคัญ

สรุป: สารยึดติดแบบเปลี่ยนสีช่วยลดสารยึดติดที่ตกค้างและใช้เวลาในการกรอน้อยกว่าแบบสัญนิยม ด้ามกรอความเร็วต่ำลดการสูญเสียความหนาของเคลือบฟันแต่ใช้เวลาในการกรอมากกว่าด้ามกรอความเร็วสูง

คำสำคัญ: การสูญเสียเคลือบฟัน การถอดแบร็กเกต สารยึดติดแบบเปลี่ยนสี การศึกษาแบบ 3 มิติ

CCL and CCH groups consisted of 21 and 19 samples, respectively. Samples of CLA type were divided into 2 groups randomly: CLL and CLH groups consisted of 20 samples each. Adhesive remnants of CCL and CLL groups were ground by carbide burs with low speed handpiece, while those of CCH and CLH groups were ground by the same bur with high speed handpiece. Grinding time was recorded. Teeth were finally scanned (after-adhesive removal scan). After-debonding and after-adhesive removal scans were superimposed on the initial scan to quantify surface changes. The results were statistically analyzed with Kruskal-Wallis test (α =0.05).

Results: After debonding, the areas and volumes of adhesive remnants bulks for CCA type were lesser than those of CLA type with significant differences. After-adhesive removal, CCA type had enamel loss in depth and volume lesser than those of CLA type but the differences were insignificant. Low speed handpiece significantly reduced enamel loss in depth compared to high speed handpiece but the reduction in volume loss was not significant. After-adhesive removal, CCA type left lower residual adhesive than CLA type with significant differences except for CCH and CLH groups which did not show significant differences. Adhesive removal with low speed handpiece significantly left more residual adhesive thickness and volume on enamel surface than those of high speed handpiece in CLA type. Debonding procedures for CCH group was least time consuming followed by those of CLH, CCL and CLL groups respectively with significant differences.

Conclusion: The color-change adhesive showed lower residual adhesive remnant and lesser time consumption in removing residual adhesive than conventional light-cured adhesive. Low speed handpiece reduced enamel loss in depth but consumed more time in adhesive removal than those of high speed handpiece.

Keywords: enamel loss, bracket debonding, color-change adhesive, 3-dimensional study

Introduction

Orthodontic adhesive has been continuously developed to improve physical properties, reduce polymerization shrinkage and simplify bonding procedure. The substantial advancement of orthodontic adhesive bond is a mixed blessing. The stronger the bond to enamel, the harder it is to debond and remove the resin. Color-change adhesive has been introduced lately and offered the advantage of high adhesive visibility during bracket placement and adhesive removal. A color-change adhesive Grẽngloo™ (Ormco Corp., California, USA) was claimed to have higher traumatic impact resistance and could change color into green with water spray from high speed handpiece or low speed handpiece during grinding process. Another color-change adhesive Transbond™ Plus Color Change (3M Unitek , California, USA) was found to completely fade away its pink color during curing. Armstrong et al also reported that this material was effective on typodont but clinically disadvantageous. However, no method of visualization was used during adhesive removal in the study.[1]

Bond strength of orthodontic brackets to the enamel should be high enough to maintain the brackets in place during treatment period and to resist occlusal loads as well. The bonding performance of Grẽngloo™ and Blũgloo™ (Ormco Corp., California, USA) was preferable to Transbond™ Plus Color Change.[2] Moreover, Delavarian reported that the shear bond strengths of Grẽngloo was higher than that of Transbond™ XT (3M Unitek, California, USA), the conventional light-cured adhesive used in this study. However, the adhesive remnant after-adhesive removal of Grẽngloo™ and Transbond™ XT was not different.[3]

After orthodontic treatment, brackets are debonded with mechanical instruments and the remaining adhesives are usually removed with rotary instruments which can cause iatrogenic enamel damage.[4-6] Moreover, insufficient removal of adhesive remnants could lead to morphological changes of enamel surface, resulting in changes in tooth color and increase plaque accumulation.[7]

The commonly used burs for adhesive-removal are carbide burs which are found to be more effective and less time consuming than Sof-Lex™ discs, ultrasonic tools, hand instruments, rubbers or composite burs. Even though, carbide burs could cause enamel damage and surface roughness, they are preferable to Arkansas stones, green stones, diamond burs, steel burs, and lasers.[8] Different protocols have been recommended for removal of adhesive remnants, such as using carbide burs at low speed[9,10], carbide burs at high speed with adequate air cooling, while other studies suggested using water spray instead of air cooling.[11-13]

Even though there are several studies on protocols for adhesive removal after bracket debonding, no ideal protocol has been developed.[7] In fact, most studies have evaluated enamel surface roughness after adhesive removal.(4,14,15) A systematic review could not conclude either an effective method to measure enamel surface roughness or residual adhesive on enamel surface after debonding. The study concluded that new techniques should be developed for effective removal of residual adhesive and minimization of surface enamel wear during debonding.(7) Moreover, no study has compared the effects of color-change adhesive and conventional adhesive after orthodontic debonding.

The development in 3D technology allowed quantitative measurement in minor changes on enamel surfaces after bracket debonding.(6,16-18) A 3D scanner can be used to precisely quantify *in vitro* enamel loss following bracket debonding. Pre and post debonding enamel loss can also be compared by measuring volume and depth loss with 3D scanner.(19) Post-debonding of metal brackets reveal adhesive remnants along with 20 to 50 micrometres enamel wear after-cleanup.(16)

The aims of this study were to assess and compare the adhesive remnants and enamel loss of color-change adhesive to conventional light-cured adhesive after bracket debonding and adhesive removal with low and high speed handpiece. A three-dimensional optical scanner was used to precisely quantify the enamel surface changes before bracket bonding, after-debonding and after-adhesive removal.

Materials and Methods

This study was reviewed and approved by the ethics committee (No.031/2018) of Rajavithi Hospital, Department of Medical Services, Ministry of Public Health, Bangkok, Thailand.

1. Tooth specimen preparation

Specimens of 80 human maxillary premolars, extracted for orthodontic purposes, were carefully cleaned and stored in an aqueous solution of 0.1% thymol at room temperature to prevent dehydration. Teeth with visible caries, cracks, decalcification or discoloration on buccal surface were excluded. Before the experiment, teeth were rinsed and randomly divided into 4 groups presented in Table 1. The teeth were placed centrally in the mould with root embedded in self-cured acrylic resin 3 mm below cervical line. The buccal surfaces were parallel to one side of the mould for operating convenience. For superimposition purpose, reference points were pitted on all teeth by a high speed handpiece with round diamond bur of 0.5 mm diameter in 8 positions, 1 mm below marginal ridge and 1 mm above cervical line on the mesio-buccal, mesio-lingual, disto-lingual and disto-buccal line angle. The specimens were kept in distilled water at room temperature except during bonding and testing procedures.

2. Bonding and debonding

A baseline scan (initial scan) of all teeth was obtained using a 3D optical intraoral scanner (TRIOS® Pod, 3-Shape, Copenhagen, Denmark). The scanner has an accuracy of 22.17 micron.(20) The teeth were polished with nonfluoridated pumice for 10 seconds, then rinsed and dried. The enamel surfaces were treated with 37% phosphoric acid etching gel for 30 seconds, rinsed, and completely dried until frosty enamel surfaces were gained.

ตารางที่ 1 *สารยึดติดและด้ามกรออย่างละ 2 ชนิดแบ่งเป็นกลุ่ม 4 กลุ่มที่ใช้สารยึดติดและด้ามกรอที่แตกต่างกันในกระบวนการทำความสะอาด*

Table 1 *Two type of adhesive and two type of handpiece and four groups with different adhesives and devices for cleanup process.*

Adhesive Type	Handpiece Type	Group
Color-change adhesive (CCA)	Low-speed handpiece	CCL
	High-speed handpiece	CCH
Conventional light-cured adhesive (CLA)	Low-speed handpiece	CLL
	High-speed handpiece	CLH

Stainless steel brackets for maxillary first premolar (Gemini, 0.022-inch twin, 3M Unitek, Monrovia, California, USA) were bonded on the enamel of the teeth according to the manufacturer's instructions with 2 orthodontic adhesives; color-change adhesive, Grẽngloo™ (Ormco Corp., California, USA) and conventional light-cured adhesive, Transbond™ XT (3M Unitek, California, USA). The brackets were placed in the center of buccal surface, 4 mm below buccal cusp tip. Hand instrument with moderate pressure was used to completely seat brackets to tooth surface. All excess adhesive was carefully removed with an explorer probe. The teeth were light-cured with a visible light curing unit at 1,470 mW/cm^2 (Elipar™ DeepCure-S LED Curing Light, 3M, USA) for 20 seconds (10 seconds from the mesial edge and 10 seconds from the distal edge of bracket). In order to achieve complete polymerization of the adhesive, teeth were stored in distilled water for 24 hours. Later, all brackets were debonded by bracket-removing pliers (3M Unitek, California, USA) with gentle squeezing, leaving adhesive bulk on buccal surface. The post- debond scans were then obtained for all teeth (after-debonding scan).

3. Adhesive-removal

40 samples of color-change adhesive (CCA type) were divided into 2 groups randomly: CCL and CCH groups consisted of 21 and 19 samples, respectively. Another 40 samples of conventional light-cured adhesive (CLA type) were divided into 2 groups randomly: CLL and CLH groups consisted of 20 samples each. Adhesive remnants of CCL and CLL groups were ground by carbide burs with low speed friction-grip handpiece (WE-57T air low speed handpiece,W&H Dentalwerk Bürmoos GmbH, Bürmoos, Austria), while those of CCH and CLH groups were ground by the same bur with high speed handpiece (Pana max plus model PAP-SU M4, NSK, Japan). These 2 types of handpiece used the same friction grip 12 fluted carbide bur (Adhesive Removal Bur #118L, Reliance Orthodontic Products Inc., Illinois, USA). During adhesive remnant removal, water spray was used for clearance and heat reduction for all teeth. In CCL and CCH groups, water spray reduced tooth surface temperature turning adhesive color into green (Figure 1). The adhesive was removed until the enamel surface seemed smooth and clean to the naked eye under the light from operatory lamp. To reduce variability, all procedures were performed by the single operator. Grinding time of each teeth was recorded and all teeth were scanned (after-adhesive removal scan).

4. Adhesive remnants and enamel change evaluation

All scans were saved in standard tessellation language (STL) format and exported to Geomagic Studio software (3D System Inc., South Carolina, USA). Initial (Figure 2A), after-debonding, and after-adhesive removal (Figure 2D) scans were superimposed on 8 reference points and use the best fit alignment function to evaluate the changes on enamel surface where bracket had been placed (Figure 2B, E). The superimposition was fitted at least 90% of the unchanged surface areas (not affected

รูปที่ 1 *ความเย็นจากการพ่นน้ำของด้ามกรอความเร็วต่ำและความเร็วสูงทำให้สารยึดติดแบบเปลี่ยนสีกลายเป็นสีเขียว*

Figure 1 *Image of a tooth with adhesive remnant after bracket debonding. A color-change adhesive turned green when cooled by water spray from low speed or high speed handpiece.*

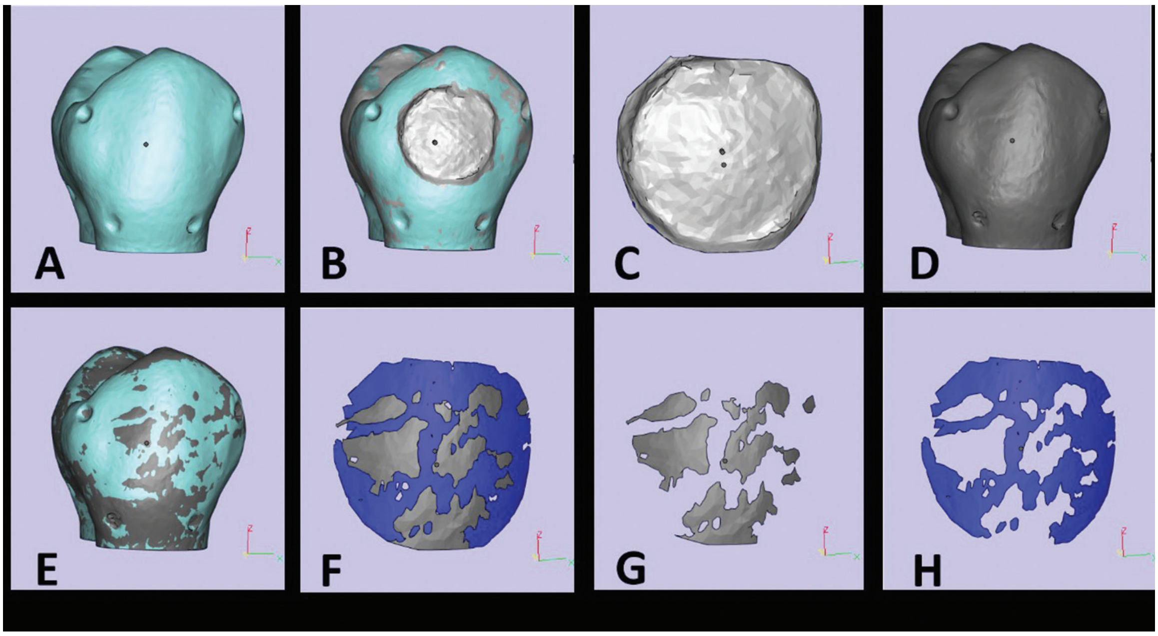
by the bracket placement) within 25 micron.[21] If the superimposition did not meet this requirement, that samples were excluded from the study. After superimposition, changes were evaluated with linear color scale. The outlines of the area where brackets had been bonded were traced and surface changes within those areas were calculated using Geomagic Studio software. Areas that showed adhesive bulk, adhesive remnant areas and volume were analyzed (Figure 2C). Ground adhesive remnant and enamel loss were calculated separately to avoid loss and gain canceling each other out (Figure 2F, G and H). The grinding time, volume and area of adhesive bulk, volume and depth of enamel loss, thickness and volume of adhesive remnants were compared among the 4 groups.

Statistical Analysis

Results from this study did not pass Shapiro-Wilk normality test, therefore, Kruskal-Wallis and Dunn's tests were used (α at 0.05).

Results

Of the 4 samples, 2 from CCL group and 1 each from CCH and CLH groups were excluded from the study due to incomplete scans and improper fit of the superimposition (less than 90% fit of the unchanged surface within 25 micron). The remaining



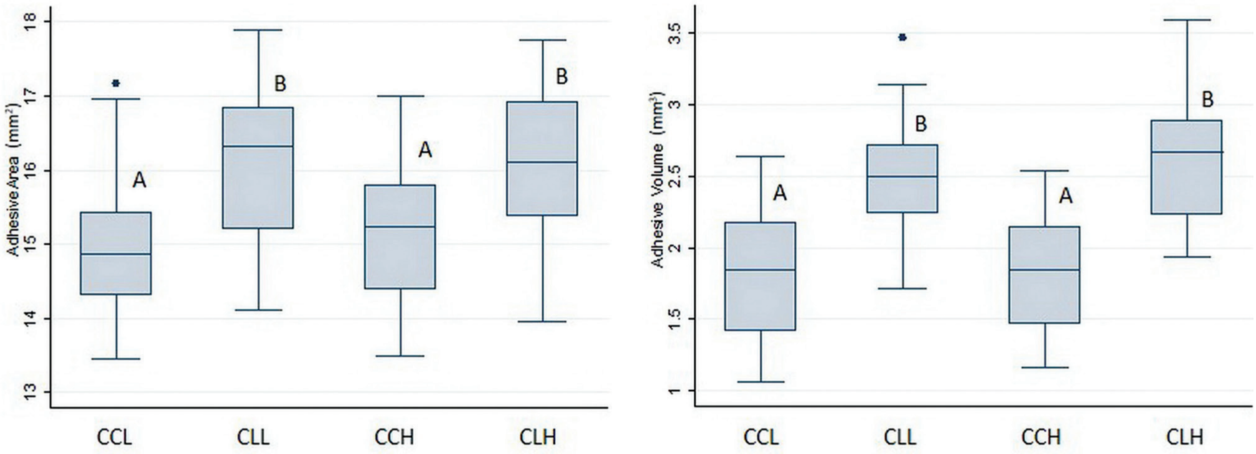
รูปที่ 2 *(A) ภาพสแกนแรก (B) ภาพสแกนแรก (สีฟ้า) ซ้อนทับกับภาพสแกนหลังถอดแบร็กเกตโดยใช้จุดอ้างอิง 8 จุด ส่วนสีเทาอ่อนเป็นสารยึดติดที่ค้างอยู่ (C) สารยึดติดที่ค้างอยู่ถูกแยกออกมาเพื่อคำนวณหาพื้นที่และปริมาตร (D) ภาพสแกนหลังกรอสารยึดติด (E) ภาพสแกนแรกซ้อนทับกับภาพสแกนหลังกรอสารยึดติด (สีเทา) (F) สารยึดติดตกค้าง (สีเทา) ถูกแยกออกจากเคลือบฟันที่เสียไป (สีน้ำเงิน) ภายหลังการกรอสารยึดติด (G) สารยึดติดตกค้างถูกคำนวณหาความลึกและปริมาตร (H) เคลือบฟันที่สูญเสียไปถูกคำนวณหาความลึกและปริมาตร*

Figure 2 *(A) The initial scan (B) The initial scan, light blue color, was fitted with the after-debonding scan. The superimposition using 8 reference pits showed adhesive bulk, light gray color. (C) The adhesive bulk after bracket debonding was subtracted and calculated for adhesive area and volume. (D) The after-adhesive removal scan. (E) The initial scan was fitted with the after-adhesive removal scan, gray color. (F) After-adhesive removal process, adhesive residual (gray color) and enamel loss (blue color) were subtracted. (G) Enamel loss was calculated separately for depth and volume loss. (H) Residual adhesive after-adhesive removal was calculated for adhesive thickness and volume.*

sample sizes were 19, 18, 20 and 19 teeth for CCL, CCH, CLL and CLH groups, respectively.

The results from 3D scans showed that all teeth had adhesive bulks left on the tooth surfaces after-debonding (Figure 3). There were only 2 samples that presented enamel lost in this process, one for CCL group and one for CLL group. The area of enamel loss was less than 5%. The areas and volumes of adhesive bulks after-debonding for CCL and CCH groups (CCA type) were less than those of CLL and CLH groups (CLA type) with significant differences (P = 0.00013 for area and P = 0.00010 for volume). However, no significant difference was found within CCL and CCH groups (P = 0.54336 for area and P = 0.87924 for volume) and within CLL and CLH groups (P = 1.00000 for area and P = 0.24932 for volume).

Concerning loss of the tooth structure, adhesive removal process also removed a small amount of enamel. The median of enamel loss depths were



รูปที่ 3 *กราฟกล่องแสดงพื้นที่ (ตารางมิลลิเมตร) และปริมาตร (ลูกบาศก์มิลลิเมตร) ของสารยึดติดหลังถอดแบร็กเกต*
**ตัวอักษรที่ต่างกันแสดงว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p \leq 0.05$)*

Figure 3 *Box plot showing areas (mm^2) and volume (mm^3) of adhesive bulks on the tooth surface after-debonding.*
**Different letters indicate statistical differences between groups; $p \leq 0.05$.*

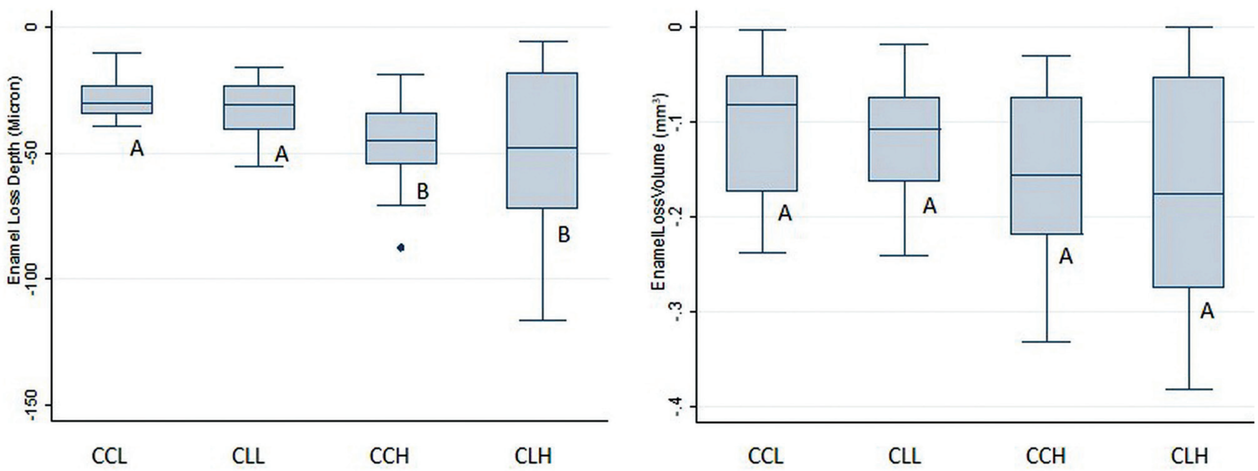
ตารางที่ 2 *ค่าเฉลี่ยความลึกและปริมาตรของการสูญเสียเคลือบฟันหลังการกรอสารยึดติด*
**ตัวอักษรที่ต่างกันแสดงว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p \leq 0.05$)*

Table 2 *An average enamel loss depth and volume after-adhesive removal*
**Different letters indicate statistical differences between groups; $p \leq 0.05$.*

Groups	n	Median	25th percentiles	75th percentiles	Min	Max	
Enamel loss Depth (micron)							
CCL	19	30.2	23.5	34.5	10.1	39.4	A
CLL	20	30.9	23.6	40.6	16.2	55.1	A
CCH	18	45.0	34.2	54.3	19.0	87.5	B
CLH	19	48.0	18.4	71.8	5.8	116.5	B
Enamel loss Volume (mm^3)							
CCL	19	0.0819	0.0520	0.1739	0.0024	0.2384	A
CLL	20	0.1074	0.0748	0.1616	0.0188	0.2411	A
CCH	18	0.1566	0.0741	0.2184	0.0298	0.3313	A
CLH	19	0.1762	0.0529	0.2745	0.0003	0.3811	A

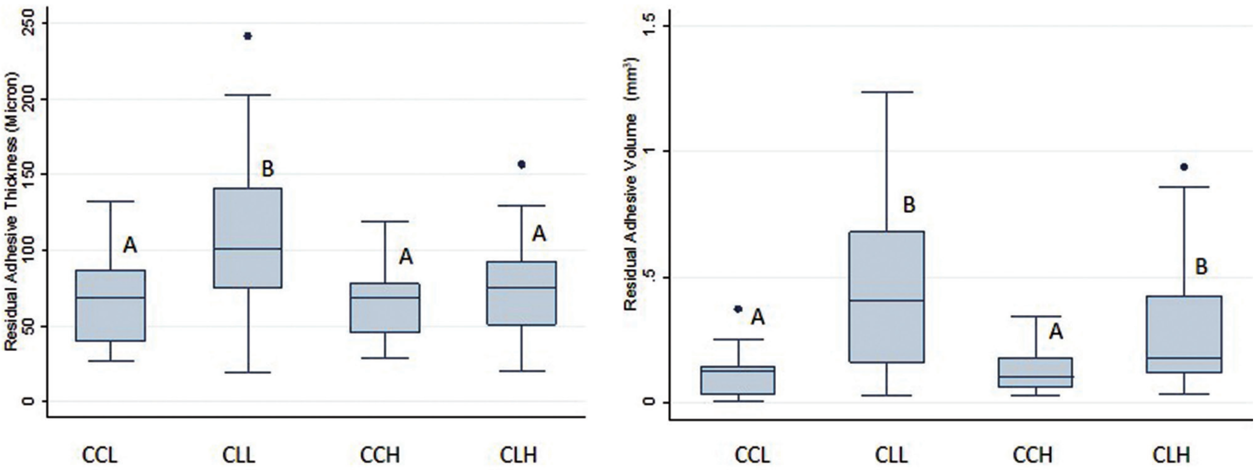
30.2, 30.9, 45.0 and 48.0 micron while the enamel loss volumes were 0.0819, 0.1074, 0.1566 and 0.1762 mm3 for CCL, CLL, CCH and CLH groups respectively (Table 2 and Figure 4). In view of adhesive type, CCA type with low and high speed handpiece had enamel loss depths less than those of CLA type after-adhesive removal with no significant difference. Considering speed of handpiece, cleanup with low speed handpiece reduced enamel loss in terms of depth and volume in comparison with high speed handpiece with significant differences (P = 0.000967 for CCA type and P = 0.016875 for CLA type). However, the difference of enamel loss volume was not significant among 4 groups.

After-adhesive removal, CCA type left lesser residual adhesive than CLA type with significant difference except the comparison of thickness between CCH and CLH groups (Figure 5). CCL



รูปที่ 4 *กราฟกล่องแสดงความลึก (ตารางมิลลิเมตร) และปริมาตร (ลูกบาศก์มิลลิเมตร) ของการสูญเสียเคลือบฟันหลังกรอสารยึดติด*
**ตัวอักษรที่ต่างกันแสดงว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p \leq 0.05$)*

Figure 4 *Box plot showed enamel loss depth (micron) and enamel loss volume (mm3) after-adhesive removal.*
**Different letters indicate statistical differences between groups ($p \leq 0.05$).*



รูปที่ 5 *กราฟกล่องแสดงความหนา (ตารางมิลลิเมตร) และปริมาตร (ลูกบาศก์มิลลิเมตร) ของสารยึดติดตกค้างหลังกรอสารยึดติดออก*
**ตัวอักษรที่ต่างกันแสดงว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p \leq 0.05$)*

Figure 5 *Box plot showing residual adhesive thickness (micron) and residual adhesive volume (mm3) after-adhesive removal.*
**Different letters indicate statistical differences between groups ($p \leq 0.05$).*

group had less adhesive residual thickness than CLL group with significant difference (P = 0.002219). CCL and CCH groups also left lesser residual adhesive volume than CLL and CLH groups with significant differences (P = 0.001008 and P = 0.026664, respectively). Regarding handpiece type, cleanup with low speed handpiece likely left more residual adhesive thickness on enamel surface than cleanup with high speed handpiece for both CCA type (insignificant difference) and CLA type (significant difference P = 0.014377). The difference of residual adhesive volume was not significant among CCA and CLA type.

Debonding procedure for CCH group was least time consuming followed by those for CLH, CCL and CLL groups with significant differences (P = 0.00198) (Table 3).

Discussion

Several studies have evaluated the accuracy of intraoral scanners. Tomita, *et al.*[20] reported that Trios pod had an accuracy of 22.17 micron. Nedelcu, *et al.*[21] studied 7 intraoral scanners and found the topographic variation of Trios pod. The deviation can be analyzed from the histogram showing an even distribution of most deviations within the nominal area ± 25 μm. Therefore, at least 90% of the unchanged surface areas within 25 micron will meet the selection criteria. Using the benefit of 3D scans, we are able to quantify and compare enamel loss and residual adhesive among the initial, after-debonding and after-adhesive removal steps using Geomagic Studio software.

Alencar, *et al.*[22] reported that the aid of headlight magnifying glass was unable to help decrease the remnant areas of Transbond™ Plus Color Change (3M Unitek, California, USA) in comparison with those of conventional light-cured adhesive. With the same point of comparison, this study found fewer remnant areas and volume of Grĕngloo™ without any seeing aids. The result may come from a strong contrast between Grĕngloo™ and tooth that help operator better remove excess adhesive flash.

Superimposition of the initial and after-debonding scan showed the adhesive bulk after bracket debonding. Most of them had composite resin remained on the tooth surface. There were only 2 tooth that presented enamel lost in this process, one in Grĕngloo™ group and the other in Transbond™ XT group. However, the area of enamel loss was less than 5%. This finding complies with those of Pont, *et al.*[23] which showed that enamel can be present on debonded brackets. But the amount of enamel found on the metal bracket was small, with only 2% of the brackets having more than 5% of their bracket area covered in enamel. Enamel loss after-adhesive removal was the result from grinding while the amount of enamel loss from bracket debonding was not significant.

ตารางที่ 3 *เวลา (วินาที) ที่ใช้ในการกรอสารยึดติด*
**ตัวอักษรที่ต่างกันแสดงว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติ (p≤ 0.05)*

Table 3 *Time required (seconds) for adhesive removal.*
**Different letters indicate statistical differences between groups; p ≤ 0.05.*

Groups	n	Median	25th percentiles	75th percentiles	Min	Max	
CCL	19	37.39	30.43	40.44	25.83	47.91	A
CLL	20	50.28	43.54	59.20	39.47	61.37	B
CCH	18	17.31	14.46	20.48	13.11	24.77	C
CLH	19	27.11	23.81	30.86	21.56	36.60	D

The earlier study reported that the mean value of resin tags observed by confocal microscopy was 8.7 micron(24), which may be explained by the high viscosity of the adhesive employed and the cross-striations and craters of intact enamel.(25) To completely clean the adhesive remnant, the resin tags, etched enamel and enamel surface must be removed inevitably.

Regarding adhesive type, color-change adhesive group had less depth and volume of enamel loss than those of conventional light-cured adhesive after-adhesive removal with insignificant difference for both low and high speed handpiece groups. The result may derive from the sharp difference between enamel surface and color-change adhesive that helps facilitate the elimination of adhesive remnants. However, the distinction is gradually decreased and entirely unnoticeable at the end of process. Therefore, adhesive remnant should be carefully ground when all of the adhesive is nearly removed.

Considering bur speed, there were significant differences in the enamel loss depth and insignificant differences in the enamel loss volume. Low speed group has less enamel loss than high speed handpiece group. These findings were exactly the same as the other report.(7) To recap the benefit of color-change adhesive, grinding adhesive remnants by carbide bur with low speed, coupled with water spray, has led to the distinction between Grẽngloo and the teeth. Cooling the temperature down from water spray also help save the pulp vitality.

In this study, the mean of enamel loss depth after-adhesive removal with a low speed handpiece was 30.9 micron less than those of studies done by Ryf, *et al.*(18) and Al Shamsi, *et al.*(16) which showed the mean depths of 44.9 micron and 50.5 micron respectively. The dissimilar results were derived from the differences in materials used (brackets and adhesive), different experiment conditions and different methods of measurements or calculation.

The findings of this study revealed that scarring of enamel after-debonding procedures was inevitable but could be reduced by choosing the right protocol. Using low speed tungsten carbide bur appeared to be the most efficient method of removing adhesive residue after-debonding, producing lesser amount of enamel loss and scars.

To avoid the consequence of leaving the unnoticeable adhesive on enamel surface at the end of cleanup process, polishing burs, such as PoGo® and One Gloss™, must be employed to remove all unseen remnants, smooth enamel surface and prevent white spot and staining(10,26).

Debonding procedure of color-change adhesive group was less time-consuming for both low speed and high speed handpiece groups with significant differences. Strong contrast between color-change adhesive remnant and enamel surface acting as a dividing line helps orthodontist notice the boundary of color-change adhesive and enable faster and easier way to get rid of the adhesive remnants. Moreover, smaller area and volume of color-change adhesive bulk need lesser time to cleanup. Time required for resin removal by high speed handpiece groups was less than that of low speed groups, even though cleanup with high speed handpiece proves to be unsuitable for the cause of enamel loss. It is recommended that adhesive remnants should be ground with low speed to preserve enamel. If necessary, carbide bur with high speed handpiece should be employed with caution.

Conclusion

The advanced 3D measurement technology enables the quantitative research on enamel surface change. The color-change adhesive showed lower residual adhesive remnant and lesser time consumption in removing residual adhesive than conventional light-cured adhesive. Low speed handpiece reduced enamel loss in depth but consumed more time in adhesive removal than those of high speed handpiece. Yet, further studies are necessary to draw more definite conclusions concerning the advantages of this type of adhesive.

Acknowledgment

The authors are grateful to Dr. Pornkana Asavanamuang, Dr. Sivaporn Sachdev and Mr. Jaturong Jitsaard for mentorship and advice.

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