Debonded Enamel Surface Roughness After Different Polishing Methods: An Atomic Force Microscopy

ความหยาบผิวเคลือบฟันที่ถูกดีบอนด์หลังขัดด้วยวิธีที่ต่างกัน: การศึกษาด้วยกล้องจุลทรรศน์แรงอะตอม

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ABSTRACT

This study attempted to compare and evaluate the enamel surface roughness post-removal of orthodontic brackets and post-polishing by white stone bur (Group I), Sof-Lex disc (Group II), tungsten carbide bur (Group III), and sandblasting method (Group IV), by using an atomic force microscope (AFM). Briefly, four groups of human premolars (n = 20 for each group) underwent bracket-bonding and thermocycling procedures. Then, adhesive remnants were assessed using a composite remnant index and the teeth were polished by the mentioned methods. Time consumptions for completely removing each sample's adhesives were recorded. Using an AFM, evaluations of both pre- and post-debonded surface roughness were performed. Data were analyzed using paired t-test and one-way ANOVA. The results showed that Group III consumed significantly shortest time for removing the residual adhesives, followed by Groups I, II, and IV, respectively (P<0.001). The greatest roughness of post-debonded enamel surface was detected in Group I, followed by Groups III, IV, and II, respectively. Some significant differences in the surface roughness were found among groups (P=0.004), except in those between Groups I and III and between Groups II and IV. This AFM study illustrated that enamel surface roughness was more affected by white stone and tungsten carbide burs than by Sof-Lex and sandblasting, in case that residual adhesives needed to be removed.

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เปรียบเทียบและประเมินความหยาบผิวเคลือบฟัน หลังถอดแบร็กเกตและตามด้วยการขัดโดยหัวกรอหินสีขาว (กลุ่ม 1) แผ่น Sof-Lex (กลุ่ม 2) หัวกรอทังสเตนคาร์ไบด์ (กลุ่ม 3) และการพ่นทราย (กลุ่ม 4) ด้วยการใช้กล้องจุลทรรศน์แรงอะตอม (เอเอฟเอ็ม) วิธีการ โดยสังเขป คือ ฟันกรามน้อยของมนุษย์ 4 กลุ่มดังกล่าว (n = 20 ในแต่ละกลุ่ม) ผ่านกระบวนการยึดด้วยแบร็กเกตและเทอร์โมไซคลิง หลังจากนั้น ประเมินส่วนเหลือของสารยึดติดด้วยดัชนีคอมโพสิตคงเหลือและขัดฟันด้วยวิธีตามกล่าวข้างต้น บันทึกเวลาที่ใช้กำจัดสารยึดติดจากชิ้นตัวอย่าง และประเมินความหยาบผิวทั้งก่อนและหลังดีบอนด์ด้วยเอเอฟเอ็ม ทดสอบความแตกต่างค่าเฉลี่ยระหว่าง 2 ประชากรที่ไม่เป็นอิสระกันและวิเคราะห์ความแปรปรวนทางเดียว ผลการศึกษา พบว่า กลุ่ม 3 ใช้เวลาน้อยที่สุดเพื่อกำจัดส่วนเหลือของสารยึดติด ตามด้วยกลุ่ม 1, 2, และ 4 อย่างมีนัยสำคัญทางสถิติ (P<0.001) ความหยาบสูงที่สุดของผิวเคลือบฟันหลังดีบอนด์ พบในกลุ่ม 1 ตามด้วยกลุ่ม 3, 4, และ 2 ตามลำดับ โดยพบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างกลุ่ม (P=0.004) ยกเว้นระหว่างกลุ่ม 1 กับ 3 และระหว่างกลุ่ม 2 กับ 4 การศึกษาด้วยเอเอฟเอ็มนี้ แสดงว่า ความหยาบผิวเคลือบฟันได้รับผลกระทบจากหัวกรอหินสีขาวและหัวกรอทังสเตนคาร์ไบด์ มากกว่าจากแผ่น Sof-Lex และการพ่นทราย ในกรณีที่จำเป็นต้องกำจัดส่วนเหลือของสารยึดติด

Keywords: Enamel surface roughness, Debonding, Atomic Force Microscope
คำสำคัญ: ความหยาบผิวเคลือบฟัน การดีบอนด์ กล้องจุลทรรศน์แรงอะตอม

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Introduction

Fixed orthodontic appliances for the corrections of some malocclusions are dealt with the use of resin adhesive for bonding the brackets on the teeth. After an orthodontic treatment's active phase is finished, such appliances are to be pulled out and the aligned teeth need some cleaning procedures to make sure no adhesive remnants left on their surfaces. Some polishing instrument for removing the adhesives may create scratches or irregularities on the enamel surface. This situation results in its surface roughness. Consequently, some iatrogenic problems in both esthetic and functional aspects are induced to the enamel (Zachrisson and Arthun, 1979; Artun and Bergland, 1984, Hong and Lew, 1995).

Some polishing methods have been introduced to provide as smooth enamel surface as possible, when the adhesive removal is indicated. They include the use of hand scaler, ultrasonic scaler, LASER, and numerous types of rotary instrument, that is, green stone, white stone, diamond, tungsten carbide, composite burs, as well as Sof-Lex discs (Burapavong et al., 1978; Retief and Denys, 1979; Krell et al., 1993; Campbell, 1995; Zarrinnia et al., 1995; Hosein et al., 2004; Karan et al., 2010; Ahrari et al., 2013). A sandblasting method, an air-abrasion with aluminium oxide particles, is also recommended (Reisner et al., 1997; Kim et al., 2007; Mhatre et al., 2015). Among several polishing techniques from previous researches, the most suitable and harmless one is still controversial.

Previous evaluation studies on the enamel surface roughness are performed by using a scanning electron microscope (SEM). Owing to the fact that the numerical scoring indices for the surface roughness are dependent on each investigator (Retief and Denys, 1979; Campbell, 1995; Zarrinnia et al., 1995; Osorio et al., 1998, Smith et al., 1999; Ulusoy, 2009), the device provides some qualitative, but not quantitative, evaluations. Because of its concomitant provision of high resolution scanning with two- and three-dimensional image creations, an atomic force microscope (AFM) is better and more reliable for an evaluation of the surface roughness than SEM (Binnig et al., 1986; Tholt de Vasconcellos et al., 2006; Kakaboura et al., 2007). In addition, a quantitative measurement can be performed by some value outcomes' interpretations.

Objective of the study

The objective of this study was to compare and evaluate the enamel surface roughness post-removal of orthodontic brackets and post-polishing by four different methods (white stone bur, Sof-Lex disc, tungsten carbide bur, and sandblasting method) by means of an atomic force microscope (AFM).

Methodology

Naresuan University Ethical Committee, Phitsanulok approved this study's protocol (IRB Number 0697/2017).

Sample preparations

Eighty human maxillary premolars with normal crown morphology and intact enamel extracted to serve an orthodontic purpose were collected. None had a history of previously bonded, fluorosis, crown fracture, carious lesion, restorative material, crack line, or other dental defects on their buccal surfaces. To inhibit some bacterial growth, they were cleaned and stored in 0.1% thymol solution. The root's approximate 2.0 mm below cemento-enamel junction were cut off. The crowns were embedded in a plastic pipe, 2.0 cm diameter, and stabilized with self-curing acrylic resin. Their buccal surfaces were kept 1.0-1.5 mm horizontally above the plastic pipe's rim, and subjected to cleaning with pumice slurry. The samples were then randomly divided into four groups (n = 20 per group) and designated as Groups I to IV, the codes of which were marked under the pipe.

AFM

By using an AFM (Flex-Axiom; Nanosurf, Liestal, Switzerland) equipped with a scanner (a maximum range of 100x, 100x, and 5 mm in the x-, y-, and z-axes, respectively), all groups' enamel surface roughness were evaluated to obtain the pre-deboned value (served as controls). Each sample's root mean square roughness (Rq) was calculated by a software (Nanosurf C3000, Liestal, Switzerland). Evaluations of the pre-debonded Rq in each sample were carried out three times and the obtained data were averaged.

Bonding and debonding procedures

After evaluations of the pre-debonded Rq, all samples' enamel were etched using 37% phosphoric acid (Scotchbond Etchant; 3M ESPE, MN, USA), rinsed with water, and air-dried. The etched enamel was applied with a thin layer of primer (Transbond XT; 3M Unitek, CA, USA). A stainless steel bracket (3M Unitek) with a small amount of adhesive (Transbond PLUS color change adhesive; 3M Unitek) was placed on the 1/3 middle of each sample's buccal surface and the adhesive's excess was gently removed with a dental explorer. According to the manufacturers' instructions, the resin was light-cured. They were stored in distilled water at 37ºC for 24 h to prevent dehydration and to achieve maximum bond strength, followed by thermocycling (500 times at 5-50ºC for 20 sec (in each bath) and at 25ºC for 5-10 sec (inter-bath travel), according to the International Standard Organization TB 11450 standard).

The experimental groups' brackets were removed with peeling forces by a pair of bracket-removing pliers. The amount of residual adhesives was assessed and scored by using a composite remnant index (CRI), according to Hong and Lew (1995), under a stereomicroscope (Olympus SZH10; Olympus, Tokyo, Japan) at a 25x magnification.

Post-removal of the bracket, remnants of the adhesive were removed by using four different methods as follows:

Group I: a white stone bur (Dura-White Stones; Shofu, Kyoto, Japan) attached to a high-speed handpiece (120,000 rpm) with water coolant was used with a light force in a mesial-to-distal directed movement and pressing the bur's shank parallel to the tooth surface.

Group II: a Sof-Lex disc (Sof-Lex; 3M ESPE) attached to a low-speed handpiece (30,000 rpm) with air coolant and water irrigating during the polishing procedures was used in a sequence of course, medium, fine, and superfine discs with a light force in a mesial-to-distal directed movement and pressing the bur's shank parallel to the tooth surface.

Group III: a tungsten carbide bur (renew adhesive removal burs #118S; Reliance Orthodontic Products, IL, USA) attached to a high-speed handpiece (120,000 rpm) with water coolant was used with a light force in a mesial-to-distal directed movement and pressing the bur's shank parallel to the tooth surface.

Group IV: a sand-blasting technique with 50 µm aluminum oxide powder was performed perpendicularly to the enamel surface at a distance of 10 millimeter, an air pressure of approximately 7 kg/cm^2 (Micro-abrasive sandblaster; Parkell Inc, NY, USA).

The samples were rinsed by tap water and air-dried thoroughly using a moisture-free air source. All polishing procedures without any damage to the enamel surfaces were conducted by the sole investigator. The complete removal of all adhesive remnants from the enamel surfaces was carefully inspected by naked eyes combined with using the light of an LED light-cured machine and then thoroughly reconfirmed by the Olympus SZH10 stereomicroscope at 25x magnification. The time consumptions (sec) for a complete removal of the adhesive remnants in each sample were recorded.

Before the post-debonding evaluations, the coded mark in each sample was concealed with an opaque plastic tape for blinding. All experimental samples were then mingled into one large group and randomly evaluated by using an AFM. Evaluations of the post-debonded Rq in each sample were conducted in the same manners as those of the pre-debonded ones.

Statistical analyses

All numerical data were analyzed using PASW Statistics for Windows, Version 23.0 (SPSS, NY, USA). Descriptive statistics (mean and standard deviation) were used to determine pre- and post-enamel surfaces' Rq, CRI, and time consumptions for removing the adhesives. Some differences among methods were compared with a one-way analysis of variance (ANOVA), followed by Fisher's Least Significant Difference (LSD). Along with the pre-debonded surface roughness, alterations of the post-debonded ones were investigated by paired t-test. The level of statistical significance was the value of $P<0.05$.

Results

CRI and time consumptions

Each group's CRI and time consumptions for removing the adhesives (mean±standard deviation) were shown in Table 1. No inter-group statistically significant difference in the CRI was detectable ($P=0.942$). However, there were inter-group statistically significant differences in the time consumptions for adhesive removal ($P<0.001$). Group III was revealed to consume the significantly shortest time (18.53±1.45 sec), followed by Group I (22.56±3.32 sec), Group II (58.13±6.36 sec), and Group IV (85.20±4.32 sec), respectively ($P<0.001$).

Enamel surface roughness

With their AFM shown in Figures 1a-b and 1c-1j, the respective pre- and post- debonded enamel surface roughness (mean±standard deviation) were shown in Table 2.

No inter-group statistically significant difference in the pre-debonded surface roughness was observed. Nevertheless, the greatest roughness of the post-debonded surface roughness was seen in Group I, followed by Groups III, IV, and II, respectively. Apart from that between Groups I and III and that between Groups II and IV, some significant differences in the surface roughness were found among groups ($P=0.004$).

It was observable in each group that the post-debonded surface roughness was significantly higher than the pre-debonded one (P<0.001).

Table 1 Time consumptions (sec) for the removal of orthodontic adhesive materials and composite remnant index in each group. (All values are expressed in mean±standard deviation; n = 20 for each group)

Group	Composite remnant index	Time consumption
I (white stone bur)	3.80±0.70[a]	22.56±3.32[b]
II (Sof-Lex disc)	3.70±0.80[a]	58.13±6.36[c]
III (tungsten carbide bur)	3.80±0.62[a]	18.53±1.45[d]
IV (sandblasting)	3.70±0.73[a]	85.20±4.32[e]
P-value (one-way ANOVA)	0.942	<0.001

Uppercase letters (a, b, c, and d) are designated for statistically significant differences at P<0.05. The intra-column significant differences are shown by different uppercase letters. On the other hand, the intra-row non-significant differences are shown by similar uppercase letter.

Table 2 Pre- and post-debonded enamel surface roughness (Rq) in each group. (All values are expressed in mean±standard deviation; n = 20 for each group)

Group	Enamel surface roughness		P-value (paired t-test)
	Pre-debonded	Post-debonded	
I (white stone bur)	44.63±16.21[a]	66.21±12.03[b]	<0.001
II (Sof-Lex disc)	47.70±14.92[a]	51.65±13.67[c]	<0.001
III (tungsten carbide bur)	47.35±17.41[a]	63.36±12.24[b]	<0.001
IV (sandblasting)	46.08±19.08[a]	53.86±19.09[c]	<0.001
P-value (one-way ANOVA)	0.939	0.004	

Uppercase letters (a, b, c, and d) are designated for statistically significant differences at P<0.05. The intra-column significant differences are shown by different uppercase letters. On the other hand, the intra-row non-significant differences are shown by similar uppercase letter.

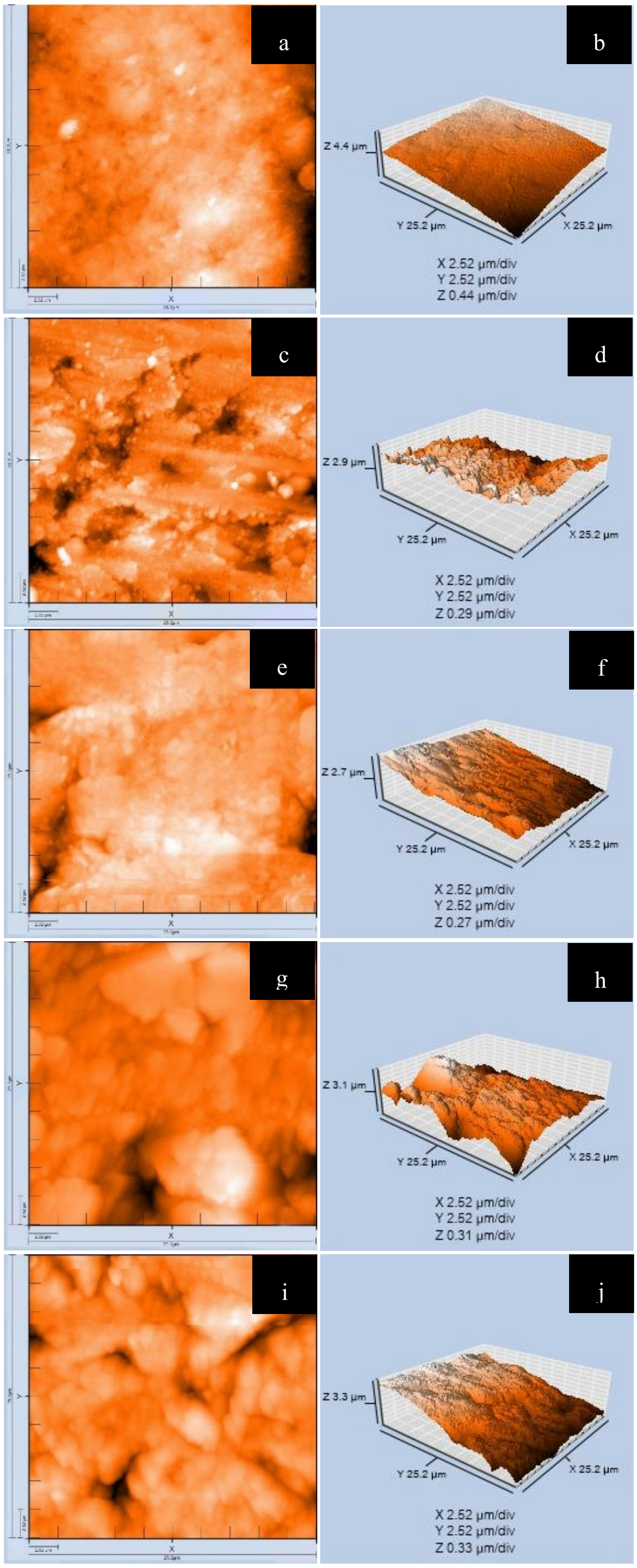

Figure 1 Two- (left column) and three- (right column) dimensional atomic force micrographs show the sample's enamel surface roughness in pre-debonded group (a-b), Group I undergone with a white stone bur (c-d), Groups II undergone with a Sof-Lex disc (e-f), Group III undergone with a tungsten carbide bur (g-h), and Group IV undergone with sandblasting (i-j).

Discussion

After removing some remnant adhesives from the enamel surfaces in this study, their post-debonded roughness became drastically differed from the pre-debonded one. In addition, different polishing methods have been revealed to cause some significant differences in the post-debonded surface roughness, particularly those observed between the white-stone/tungsten-carbide groups and the sandblasting/Sof-Lex groups.

Unlike SEM that can provide only qualitative data (Ulusoy, 2009), AFM has recently been used in some quantitative investigations into the enamel surface roughness (Karan et al., 2010; Balachandran et al., 2016; Mohebi et al., 2017), despite its more conservative (Wennerberg et al., 1999) and reliable (Russell et al., 2001; Kakaboura et al., 2007) procedures. Consequently, the comparative AFM results among several methods including sandblasting technique are scarce. Enamel surface roughness are quantitatively interpretable into various parameters such as Ra (the averages), Rmax (the distances between the highest and lowest points), and Rq (Kim et al., 2007; Karan et al., 2010; Balachandran et al., 2016; Mohebi et al., 2017). In contrast with Ra and Rmax, Rq was used in this study due to the fact that the irregularities' depth could be indicated and the shallow and deep grooves differentiated (Ozer et al., 2010; Fan et al., 2017).

Before each enamel treatment was performed, no statistically significant difference in surface roughness under an AFM was noted between the groups. On the other hand, CRI score after bracket removal also showed no statistically significant difference, when observed under a stereomicroscope. It can be assumed that there was equitable when compared the adhesive remnant removal time and enamel surface roughness by different polishing methods.

Regardless of the methods used in this study, an increase in the surface roughness occurred in all groups after adhesive removals. The phenomena of which coincided well with those in other reports (Kim et al., 2007; Ulusoy, 2009; Ahrari et al., 2013; Balachandran et al., 2016; Fan et al., 2017). Our results revealed that white stone and tungsten carbide burs caused a significantly greater Rq than sandblasting and Sof-Lex, similarly to those previously reported (Cardoso et al., 2014; Mhatre et al., 2015; Balachandran et al., 2016). However, there is a report on different methods, tungsten carbide bur and sandblasting, causes no significant difference in the post-debonded surface roughness (Kim et al., 2007). Differences in the observed areas between theirs and ours might be contributed to such discrepancies. Theirs were performed by global observations on the premolar's buccal surface, while ours were restricted to the tooth's mid-buccal area. The post-debonded surface roughness seen in the Sof-Lex group was not significantly differed from those in the sandblasting, implying their clinically similar outcomes for a patient.

With respect to the time consumptions for completely removing the adhesive remnants in this study, using a tungsten carbide bur consumed the significantly shortest time, when compared to the usage of other methods. This was consistent with those already documented (Eminkahyagil et al., 2006; Kim et al., 2007; Ulusoy, 2009; Ozer et al., 2010; Mohebi et al., 2017). By using a tungsten carbide bur, the time spent for such complete removal in the present research were approximately one-fifth and one-third of those by sandblasting and Sof-Lex, respectively. The results illustrated some more advantages of using a tungsten carbide bur to remove orthodontic adhesive remnants than using the others, in terms of time consumptions.

Due to some limitations in our study, some qualitative assessments should be included in future researches to obtain more results applicable for clinical practices.

Conclusions

Despite their less time consumptions for removing the residual orthodontic adhesives, white stone and tungsten carbide burs caused significantly more enamel surface roughness than sandblasting and Sof-Lex. Dentists should be aware of the iatrogenically induced enamel deteriorations, when white stone or tungsten carbide burs are used in clinical practices.

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