THE EFFECT OF ALTERNATIVE TECHNIQUE USING HYDRO AIR ABRASION ON ENAMEL SURFACE ROUGHNESS DURING ORTHODONTIC ADHESIVE REMOVAL

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ABSTRACT

This research aimed to evaluate and compare enamel surface change in terms of enamel surface roughness after adhesive removal by four different techniques: tungsten carbide bur with low-speed handpiece, hydro air abrasion used with aluminum oxide particles, calcium carbonate particles, and sodium bicarbonate particles. 76 human incisor extracted teeth were collected, evaluated initial surface roughness, and randomly divided into 4 groups (n = 19 for each group). Then, all the samples were bonded and removed adhesive by 4 different methods. 3D profilometer was used to evaluate enamel surface roughness before and after experiment. Data were analyzed using one-way ANOVA, Kruskal-wallis, paired t-test and Wilcoxon signed-rank test. The results of this study demonstrated that significant differences were detected among groups ($p = 0.000$). The greatest roughness was found in hydro air abrasion with aluminum oxide, followed by tungsten carbide group, hydro air abrasion with sodium bicarbonate group, and hydro air abrasion with calcium carbonate group, respectively. This study concluded that hydro air abrasion technique with calcium carbonate produced the least enamel surface roughness among other groups.

Keywords: Hydro Air Abrasion, Orthodontic Adhesive Removal, Enamel Surface Roughness

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INTRODUCTION

Following orthodontic therapy, it is necessary to remove orthodontic bracket and residual adhesive remnant. A previous study (Janiszewska-Olszowska et al., 2014) showed that after debonding, removal of residual adhesive remnant and polishing procedure, enamel structure may alter in terms of surface roughness, damage, and adhesive remnant existence. Due to these factors, various studies have been conducted to demonstrate the most effective approach for removing bracket and residual adhesive on enamel surfaces with minimal damage and high efficiency, allowing the enamel to remain in its original condition.

Aside from rotary instruments, several techniques were alternately used, such as Er:YAG (Almeida et al., 2009), intraoral sandblasting (Kim et al., 2007), and hydroabrasion (Bosco et al., 2020) to remove orthodontic adhesive. These procedures were compared to removal with tungsten carbide bur, which is regarded as a gold standard. Recent research on a hydroabrasion technique indicated that this technique was more comfortable to apply than intraoral sandblasting or air abrasion because of the limitation of particle distribution over the operative field (Bosco et al., 2020). Although the hydro air abrasion technique can be applied with a variety of powder particles, including aluminum oxide, calcium carbonate, and sodium bicarbonate, there has been no research on their effectiveness. Furthermore, a recent study (Bosco et al., 2020) assessed surface roughness using images from scanning electron microscope (SEM), which demonstrated qualitative results. A three- dimensional profilometer can be used to quantitatively determine changes in surface roughness (Salerno et al., 2019). In addition, instead of having an observer measure the images obtained from SEM, the profilometer operates using computer software. As a result, this strategy is more reliable at reducing bias during measurement.

In this study, four adhesive removal techniques: tungsten carbide bur with high-speed handpiece, hydro air abrasion used with aluminum oxide particles, calcium carbonate particles, and sodium bicarbonate particles, were used to remove orthodontic adhesive and compare the enamel surface change in terms of surface roughness through 3D profilometer.

LITERATURE REVIEWS

Currently, there are several techniques to remove remaining adhesive remnants following orthodontic bracket debonding, such as tungsten carbide bur, white stone bur, and so on. A systematic review found that using the tungsten carbide bur was the most effective procedure in terms of reduced chair time, efficiency of adhesive removal, and providing the least enamel surface roughness compared to various techniques (Janiszewska-Olszowska et al., 2014). However, each of these techniques resulted in some enamel loss and was unable to restore the enamel surface to its original condition. Several studies introduced alternative methods to rotary instruments, such as ER: YAG (Almeida et al., 2009), intraoral sandblasting (Kim et al., 2007), and more recently, hydroabrasion (Bosco et al., 2020).

1) Air abrasion or intraoral sandblasting

Aluminum oxide (Alumina) is commonly used for air abrasion. According to Reisner et al., sandblasting appears to cause less enamel damage and can be applied to polish enamel surface (Reisner et al., 1997). As a result, Kim et al. have attempted to apply this alternative method for removing residual orthodontic adhesive. They aimed to evaluate and compare this new method with the conventional use of a tungsten carbide bur. The comparison focused on several key factors: surface roughness, enamel damage, the amount of adhesive remaining on the enamel, and the time required for the procedure. They discovered that air abrasion results in enamel surface roughness that is not significantly different from that produced by a tungsten carbide bur (Kim et al., 2007). Consequently, this technique was considered as an alternative method to remove residual adhesive. Unfortunately, Cook et al. claimed that this type of particle is harder than bioactive glass, sodium bicarbonate, and glycine powder, resulting in unfavorable removal of excess tooth structure. Their findings are supported by the study, which described cutting processes and patterns using a real-time confocal microscopic imaging method (Cook et al., 2001). Moreover, it could harm our body, which went against the safety principle. Therefore, this procedure might be a concern owing to operating in the oral cavity and requires thorough protection for operators and patients against aluminum oxide particles entering the body's airway (Chen et al., 2022). As mentioned above, air abrasion can be combined with other types of particles, including bioactive glass particles. The bioactive glass has been used in air abrasion for the therapeutic remineralization of dental hard tissue. Compared to aluminum oxide, this particle has better biocompatibility, is degradable upon immersion, and releases ions that promote apatite-like phase deposition (Chen et al., 2022). Previous studies showed that using bioactive glass for air abrasion to remove orthodontic adhesive remnants causes significantly less damage to enamel compared to using alumina (Taha et al., 2017; Banerjee et al., 2008). Although both techniques increased the enamel roughness and pitted, the margin between abraded and non-abraded enamel was less defined with the bioactive glass air abrasion technique compared to alumina air abrasion (Banerjee et al., 2008). Compared to tungsten carbide bur, a bioactive glass showed minimal enamel surface damage and was more predictable than tungsten carbide bur (Banerjee et al., 2008). The result of the air abrasion technique depends on three factors, including (Banerjee et al., 2008)

- Type of abrasive powder particles

Various air-abrasion particles have been used in clinical practice, including alumina, calcium carbonate, glycine, sodium bicarbonate, and bioactive glass powder (Johnson et al., 2016). The microhardness of aluminum oxide particles is 2100 KHN, greater than the hardness of enamel (340 KHN) (Meredith et al., 1996). Consequently, it is recommended to use aluminum oxide for cutting instead of polishing. Sodium bicarbonate has a microhardness at approximately 170 KHN, whereas bioactive glass has 420 KHN. According to Johnson et al., both sodium bicarbonate and bioactive glass powders produced similar levels of enamel loss, which is not significantly different from enamel with no abrasive treatment. However, bioactive glass powder was more efficient at removing stains compared to sodium bicarbonate (Johnson et al., 2016).

- The characteristics of the air abrasion stream, for instance, the built-in physics and mechanics of the equipment, powder flow rate, and nozzle output pressure (Milly et al., 2014).
- Pressure, abrasive angle, and abrasive distance. There was an inverse relationship between cutting efficiency and distance: the greater the distance between the nozzle and substrate, the lower the cutting efficiency (Peruchi et al., 2002).

2) Hydro abrasion

Similar to air abrasion, hydro abrasion can be combined with various types of particles. Laurell KA et al. demonstrated that the air stream's reduced concentration of particles and velocity decreased when the nozzle was fixed at a 45° angle, lowering the possibility of damaging the substrate (Laurell et al., 1995). In addition, Salerno et al. suggested that the best conditions should be 45° direction and 5 mm distance to reduce substrate damage (Salerno et al., 2019). However, these particles are sprayed with water, which reduces the amount of powder particles that diffuse across the working field and its surroundings. Because of this advantage, there is a study evaluating how the hydro abrasion technique with alumina particles performs during orthodontic adhesive removal compared to tungsten carbide bur. The results showed that hydro abrasion caused less damage to the enamel surface. However, it was not as efficient in removing orthodontic adhesive as the tungsten carbide bur (Bosco et al., 2020).

3) Er:YAG

A study reported that Er:YAG laser performed better than tungsten carbide bur in terms of leaving less adhesive on the enamel surface and reducing the time required. However, the

Er:YAG laser significantly removed more enamel compared to the tungsten carbide bur (Almeida et al., 2009).

Conceptual Framework

Independent variable
Types of adhesive remnant removal techniques
- Tungsten carbide bur
- Hydro air abrasion with aluminum oxide particles
- Hydro air abrasion with calcium carbonate particles
- Hydro air abrasion with sodium bicarbonate particles

Dependent variable
Enamel changes
- Enamel surface roughness

Confounding factors
Tooth condition
- Caries
- Restoration
- Damages by extraction forceps
- Crack lines

Figure 1 Conceptual Framework

RESEARCH METHODOLOGY

This experimental study was determined to meet the criteria of the Exemption Determination by the Human Research Ethics Committee of Faculty of Dentistry, Prince of Songkla University. 76 human incisor extracted teeth were collected. The sample teeth were cleaned and stored in 0.1% Thymol solution. Human extracted upper and lower incisors with caries, restoration, crack lines, damages by extraction and other dental defects on labial surfaces were excluded from this study.

All the samples were fixed in short cylinder-shaped self-cure acrylic resin pieces made from silicone mold in 3.0 cm diameter. Celluloid tape was used to define the study area, which is 2x2 mm^2. Then, the sample teeth were evaluated for surface roughness through a 3D profilometer to get Sa values. These values were measured three times and reported in average values prior to the experiment for the pre-experimental value. All samples were randomly divided into four groups (n = 19 per group).

Aluminum oxide powder, calcium carbonate powder, and sodium bicarbonate powder were sieved to obtain a similar range of particle size (25 μm < sieved fraction < 75 μm).

Each sample, fixed in acrylic block, was etched with 37% phosphoric acid gel for 15 seconds. The etchant was rinsed off with distilled water for 15 seconds and then dried using an air spray. A thin layer of adhesive primer (Assure Plus - All Surface Light Cure Bonding Primer and Enhancer Adhesion Booster, Reliance orthodontic products, Itasca, IL, USA) was applied to the etched enamel surface, and any excess was removed with a gentle air burst for 1 to 2 seconds. Orthodontic adhesive (Pad Lock Light Cure Fluorescing Adhesive, Reliance Orthodontic Products, Itasca, IL, USA) was applied to each tooth using a silicone mold to ensure a standardized amount. The composite was then light-cured for 40 seconds with a light intensity of 1,470 mW/cm^2, directed perpendicular to the enamel surface.

Removal of adhesive remnant

After completion of the bonding procedure, different techniques of adhesive remnant removal were performed for each group of samples: Group 1: 12 fluted tungsten carbide bur with low-speed handpiece (TC composite removal bur 1171 RA, Prima Dental Manufacturing, Gloucester, UK), Group 2: hydro air abrasion with aluminum oxide particles using a prophy jet handpiece (AIR-N-GO Easy, Acteon, UK) mounted on dental unit, Group 3: Hydro air abrasion with calcium carbonate particles using the same prophy jet handpiece and dental unit, and Group 4: Hydro air abrasion with sodium bicarbonate particles using the same prophy jet handpiece and dental unit. The direction and distance between the prophy jet handpiece and enamel surface used for group 2, 3, and 4 were set up at 45° and 5 mm (Salerno et al., 2019), respectively. Also, the dental unit was set under the same condition. All teeth were removed the adhesive by the same operator.

Surface roughness evaluation

After the removal of adhesive remnants, the enamel surface roughness of all sample teeth was evaluated using a three-dimensional profilometer (Keyence 3D optical profilometer VR6200, Itasca, IL, USA). Surface roughness was assessed by the average surface area roughness (Sa), defined as the mean of the absolute values of the surface departure above and below the mean plane within the sampling area (Semnani, 2017). Sa values were measured three times for each sample and reported as average values. For surface roughness evaluation, Sa values were measured three times and reported as average values. SPSS (Statistical Package for the Social Science Software version 28, IBM Corp., Armonk, N.Y., USA) was used to analyze the surface roughness values. The distribution of each group's data was examined using the Shapiro-Wilk test. Surface roughness was compared between the four groups using one-way ANOVA or Kruskal-Wallis. The comparison group that differs from the others was identified using the post hoc test. The Paired t-test or Wilcoxon Matched Paired Test was used to assess and verify the differences between the pre- and post-experimental surface roughness. The level of significance was set at $p<0.05$.

RESEARCH RESULTS

Surface roughness before and after the adhesive removal procedure among the four groups were shown in Table 1. There was no significant difference for pre-debonded enamel surface roughness. A significant difference was found in post-debonded enamel surface roughness among groups. It was detectable that the post-debonded enamel roughness in tungsten carbide bur with low-speed handpiece group (TC) and hydro air abrasion with aluminum oxide particles group (Al) significantly increased from the pre-debonded enamel roughness. Meanwhile, the post-debonded enamel roughness in hydro air abrasion with calcium carbonate particles group (Ca) decreased from the initial one. However, in hydro air abrasion with sodium bicarbonate particles group (Na), the surface roughness before and after adhesive removal was not significantly different ($P<0.05$).

The post hoc analysis showed that the greatest roughness after removal was found in hydro air abrasion with aluminum oxide particles group, followed by tungsten carbide bur with low-speed handpiece group, hydro air abrasion with sodium bicarbonate particles group, and hydro air abrasion with calcium carbonate particles group, respectively. In addition, there was significant difference between hydro air abrasion with calcium carbonate particles (Ca) and tungsten carbide bur with low-speed handpiece group (TC), hydro air abrasion with calcium carbonate particles (Ca) and hydro air abrasion with aluminum oxide particles group (Al), and hydro air abrasion with sodium bicarbonate particles (Na) and hydro air abrasion with aluminum oxide particles group (Al) (Table 2).

Table 1 The pre-and post-debonded enamel surface roughness (Sa) in each group (n=19 for each group)

Group	Enamel surface roughness (Sa)		P-value
	Pre-debonded	Post-debonded	(Paired t-Test/Wilcoxo signed-rank test)
TC	1.12 ± 0.08	1.34 ± 0.07	0.000*
Al	1.28 ± 0.07	1.71 ± 0.16	0.011*
Na	1.11 ± 0.09	1.12 ± 0.09	0.854
Ca	1.19 ± 0.07	0.87 ± 0.06	0.000*
P-value (One-way ANOVA, Kruskal-wallis)	0.283	0.000*	

* Statistically significant with p<0.05

TC = tungsten carbide bur with low-speed handpiece, Al = hydro air abrasion with aluminum oxide particles, Na = hydro air abrasion with sodium bicarbonate particles, Ca = hydro air abrasion with calcium carbonate particles

Table 2 The post-hoc comparison (Independent Samples Kruskal-Wallis Test) of post-debonded enamel surface roughness (Sa) in each group (n=19 for each group)

Group	**Group**	**P-value**
TC	Al	0.983
	Na	0.509
	Ca	0.002*
Al	Na	0.011*
	Ca	0.000*
Na	Ca	0.357

* Statistically significant with p<0.05

DISCUSSION & CONCLUSION

According to the previous study, removal of residual adhesive remnant and polishing procedure, the enamel structure could be changed in terms of surface roughness, damage, and presence of adhesive remnant regardless of which techniques were used (Janiszewska-Olszowska et al., 2014). Although there has been research studying the performance of hydro air abrasion in orthodontic adhesive removal, it focused on adhesive remnants and enamel surface index (Bosco et al., 2020). Therefore, this study introduced alternative methods and compared the characteristics in terms of surface roughness values of enamel treated with four different orthodontic adhesive removal techniques: tungsten carbide bur with low-speed handpiece, hydro air abrasion used with aluminum oxide particles, calcium carbonate particles, and sodium bicarbonate particles. A non-contact 3D optical profilometer was applied to assess surface roughness. In order to evaluate the damage directly caused to the enamel by each technique during composite removal, no surface polishing was done following composite removal in this study.

SEM is widely used to describe and illustrate the characteristics of enamel surfaces. However, it can provide only qualitative data. To assess the surface roughness, there are several parameters that provide quantitative data, such as arithmetic average height (Ra), root mean square roughness (Rq), and ten-point height (Rz), which are widely used in many previous studies (Kim et al., 2007) (Gadelmawla et al., 2002). Nevertheless, these parameters analyze the surface along the line from a 2-dimensional (2D) measurement trace. Unlike 2D roughness parameters, 3-dimensional (3D) roughness parameters are analyzed and calculated from an area of the surface instead of a single line (Gadelmawla et al., 2002). In this study, the average surface area roughness (Sa) which is the extension of Ra to a surface and is defined as the mean of the absolute values of the surface departure above and below the mean plane within the sampling area (Semnani, 2017) was used and measured through 3D optical profilometer software.

The average surface area roughness (Sa) derived from this study showed that hydro air abrasion used with aluminum oxide produced the greatest roughness compared with other methods. That was because the microhardness of aluminum oxide particles (2100 KHN) is greater than tungsten carbide bur (1600 KHN), enamel surface (5 Mohs scale, 340 KHN), calcium carbonate particles (3.0 Mohs scale, 120 KHN), and sodium bicarbonate particles (2.5 Mohs scale) (Johnson et al., 2016). This could explain the result of the greatest roughness in hydro abrasion with aluminum oxide group in this study. However, there is no significant difference between hydro air abrasion used with aluminum oxide and tungsten carbide bur with low-speed handpiece. Calcium carbonate produced the smoothest surface, which was significantly different from tungsten carbide bur and hydro air abrasion used with aluminum oxide. Moreover, a decrease in surface roughness after adhesive removal only occurred in hydro air abrasion used with calcium carbonate group.

Hydro air abrasion with sodium bicarbonate particles was the technique that lost the most time during the study. This was followed by hydro air abrasion with calcium carbonate particles, hydro air abrasion with aluminum oxide particles, and tungsten carbide bur, which was the fastest technique. Additionally, hydro air abrasion with sodium bicarbonate was the method that used the most powder to remove the same quantity of orthodontic adhesive, followed by calcium carbonate and aluminum oxide, respectively.

In conclusion, adhesive removal using hydro air abrasion with calcium carbonate resulted in less enamel surface roughness compared to the removal with a tungsten carbide bur.

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