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Effects of removing adhesive from tooth surfaces by Er:YAG laser and a composite bur on enamel surface roughnessand pulp chamber temperature

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Abstract

Background:

At the end of fixed orthodontic treatment, the remnant of adhesive should be eliminated from the tooth surface. The purpose of this study was to compare the effect of three methods of removing adhesive on enamel surface roughness, dental pulp temperature, and also on the time spent.

Materials and Methods:

The brackets on 90 extracted teeth were debonded using bracket removal pliers. A thermocouple sensor was fitted on the buccal wall of the pulp chamber through access cavity to measure thermal changes during adhesive removal. The residue of adhesive was eliminated from enamel surface of teeth by either tungsten carbide bur, erbium-doped yttrium aluminum garnet laser, or fiber reinforced composite bur. Scanning electron micrographs images were taken to assess the roughness of enamel surface. The time spent for adhesive removal was recorded as well. Chi-square test was used to evaluate the remnants of adhesive and enamel surface roughness; *t*-test and also repeated measurement analysis of variance were applied at $P < 0.05$ to compare the thermal changes of the pulp chamber and time spent between the methods of surface treatment.

Results:

The results of surface roughness were significantly different ($P < 0.001$). The pulp temperature changed significantly ($P < 0.001$). Tungsten carbide bur increased the temperature by 5.5°C significantly slower than reinforced composite bur ($P = 0.004$), however removed the adhesive residue faster than two other methods although not significantly ($P = 0.069$).

Conclusion:

Within the limitations of this study, fiber reinforced composite bur created the smoothest enamel surface while Er:YAG laser the roughest. Tungsten carbide and composite burs generated more heat compared to Er:YAG laser. In addition, tungsten carbide bur was the fastest and Er:YAG laser the slowest devices to remove adhesive residue.

Keywords: Adhesive removal, composite bur, laser, pulp temperature, surface roughness

INTRODUCTION

Following completion of fixed orthodontic treatments and debonding of the brackets, the remnants of adhesive should be eliminated in a manner that tooth enamel remains as intact as possible. Change in the superficial layer of enamel, with the most content of minerals and fluoride, is orthodontists' concern because following the loss of enamel surface, and exposure of enamel prisms to the mouth environment and organic acids in dental plaque, the susceptibility to decalcification increases.[1]

Remnants of adhesive on enamel surface can be eliminated through different methods and instruments including: Finishing carbide bur,[2] bioactive glass air abrasion,[3] tungsten carbide bur in low or high speed hand pieces,[4] aluminum oxide air abrasion.[5,6] Rotary instrument is the contemporary technique to remove adhesive.[2] Mechanical elimination of adhesives, which are tooth colored materials, is associated with some degree of damages to enamel surface.[7] Studies show that conventional methods of adhesive removal including: Ultrasonic and hand scalers, and low speed handpiece with abrasive create visible surface roughness, 10-20 μm deep gouges, and loss of 100 μm thickness of enamel.[8] Therefore, any improvement in the technique of adhesive removal is welcomed by orthodontists. In addition, to conventional techniques, fiber reinforced composite burs and different kinds of laser such as free running erbium-doped yttrium aluminum garnet (Er:YAG),[9,10] neodymium-doped yttrium aluminum garnet,[11,12] XeCl[13] and millisecond pulsed CO_2[14] are investigated. Composite burs were initially designed to remove cement, stain, and colors from the tooth surface and were recommended for adhesive removal following orthodontic debracketing. According to the manufacturer, the fiber sections with abrasive property is the advantage of this bur. These sections of zircon/glass fibers are embedded in a matrix of resin and slowly become disintegrated in contact with a hard surface. Karan *et al*.[15] used fiber reinforced composite bur to eliminate adhesive residues. They evaluated the surface using atomic force microscopy and concluded that composite bur creates smoother surface compared to tungsten carbide bur. The studies of Almeida *et al*.[16] and Burkes *et al*.[17] showed that Er:YAG laser removed greater volume of enamel compared to tungsten carbide bur.

On the other hand, the generated heat during adhesive removal is transferred to the dental pulp and causes histopathological changes that may lead to necrosis through injury to blood vessels.[18] Zach and Cohen[19] concluded that raised temperature of the dental pulp tissue by 5.5 (°C) causes irreversible inflammation in 40% of cases, and by 11 (°C) leads to the dental pulp necrosis. Studies show that Er:YAG laser with water cooling,[17,18,20] and tungsten carbide bur without water or air cooling[21] did not significantly raise the temperature of the dental pulp tissue. We could not find any study about the effect of composite burs on temperature.

Time spent for residual adhesive removal is an important factor. David *et al*.[22] reported a cleanup time of 40 s by tungsten carbide bur in high speed hand piece.

The roughness of enamel surface has been assessed by different devices including: Linear contact measuring tools, optical three-dimensional scanners, and electron microscopy.[23] Linear contact measuring tools evaluate a limited area of the enamel surface, but optical three-dimensional scanner considers a large area.[24] Electron microscopy is a visual analyzer,[25] which is suitable to evaluate the smoothness of surfaces.[26]

Considering that no safe method has been suggested to remove residual adhesive,[26] in this *in vitro* study, the effect of three methods of removing adhesive from enamel surface roughness, dental pulp temperature, and also on the time spent was compared.

MATERIALS AND METHODS

A sample of 90 intact extracted human premolar teeth were randomly placed in three groups of 30, although the estimated sample size of each group, through a pilot study on 10 teeth at 95% coefficient of confidence and the power of 80%, was 21 cases. The teeth were kept in distilled water[25] for not more than 1 month. The water was renewed every week.[26] Following cleaning the buccal surface of teeth with fluoride free pumice paste and rubber cup in low speed handpiece, the teeth were rinsed with water and dried by air stream. Then, the surfaces were etched by phosphoric acid gel 37% (Etching agent, Resilient ortho technology, Florida, USA) for 30 s, rinsed for 15 s, and dried to appear a matt and chalky surface.[26]

A thin layer of adhesive (Resilient ortho technology, Florida, USA) was applied by a micro brush on the etched surface. A standard stainless steel edgewise premolar bracket (GAC, Central Islip, New York, NY, USA) was attached to enamel surface with composite (Resilience Ortho technology, Florida, USA), then all four edges were light cured (Top light, Taiwan) for 40 s after removing the excess composite. The samples were incubated in water for 24 h at 37 (°C)[21] before debracketing by bracket removal pliers (Ormco, CA, USA). An access to the pulp chamber was prepared in lingual surface. The teeth were divided randomly into three equal groups. Teeth surfaces were explored by microscope at ×35 magnification to assess the adhesive residue. According to adhesive remnant index (ARI), described by Artun and Bergland,[27] teeth were categorized in 4 grades: 0 = no adhesive, 1 = Less than 50% of adhesive, 2 = More than 50% of adhesive and 3 = All the adhesive remains on the tooth surface. Since no difference was found between three groups [Table 1], we tried to remove the remnant of adhesive by either eight bladed tungsten carbide bur (Geber. Brasseler, Komet-Lemgo, Germany) in low speed handpiece; Er:YAG laser at 2.94 μm, 20 Hz, 125 mJ, 2.5 W and at the distance of 5 mm; and zircon-rich glass fiber reinforced composite bur (Stainbuster Abrasive Technology Inc., Lewis Center, OH, USA) in low speed hand piece. A thermocouple sensor, connected to a microcontroller, was installed on the buccal wall of the pulp chamber through the access hole. The micro controller was recording time and temperature during the process of removing the adhesive.

Enamel surface roughness was evaluated using scanning electron micrographs (SEM) at ×100 magnification. The texture of the surface was interpreted by enamel damage index, introduced by Howell and Weekes.[28] In this index: Grade 0 is when the surface is smooth without any scratches; Grade 1 is when some scattered scratches are visible; Grade 2 is when the surface is rough with numerous deep scratches and some grooves, and Grade 3 is when deep scratches and wide groves are visible with naked eyes.

Data were analyzed with SPSS 17.0 software package (SPSS Inc., Chicago, Illinois, USA). Chi-square test was used to compare the surface roughness and residual adhesive between groups. *t*-test and also analysis of variance (ANOVA) were used to compare the time spent and thermal changes. The results were evaluated at the $P < 0.05$ significance level, with a 95% confidence interval.

RESULTS

The results of enamel surface roughness, assessed under SEM at ×100 magnification [Figures 1–3], are shown in Table 2. The comparison between groups showed that enamel surface roughness was significantly more in Er:YAG laser group, and composite bur created the smoothest surface. Figures 1 through 3 show the post-treatment image of surfaces, which are: Acceptable with fine scattered scratches created by composite bur, with coarse scratches created by tungsten carbide bur, and with wide grooves and numerous coarse scratches created by Er:YAG laser, which was the roughest, respectively.

Comparing the thermal changes in each group showed a significant decrease in Er:YAG laser group, but significant increase in two other groups. The thermal changes in groups are seen in Table 3. ANOVA revealed significant changes in groups.

The time required for increasing the temperature of the pulp chamber by 5.5°C was 56.53 s in tungsten carbide bur, and 37.86 in composite bur groups [Table 4]. In none of the cases of Er:YAG group, the temperature increased by 5.5°C. Four cases of composite bur and four cases of tungsten carbide bur groups did not show an increase in temperature of the pulp chamber by 5.5°C.

Table 5 shows the time spent in groups. The results revealed that although no statistical significant difference was found, but Er:YAG group took the longest time, while the shortest time belonged to tungsten carbide bur group.

DISCUSSION

Regardless of the methods used, some enamel scarring occurs after debracketing and adhesive removal. However, the advantages of bonding orthodontic attachments unquestionably outweigh the disadvantages. Cleaning up of residual bonding resin following debracketing needs to be in a manner that the enamel surface remains intact as much as possible. Hence, the clinician must be aware of the best methods for minimizing enamel damage.

The results of the present study implied that the texture of enamel surfaces, following adhesive removal in the three groups is different. Composite bur created the smoothest, and Er:YAG laser the roughest surfaces, although at the minimum related power setting. Almeida *et al*.[16] and Burkes *et al*.[17] showed that Er:YAG laser removed more enamel compared to tungsten carbide bur. In the present study, and the study of Karan *et al*.[15] tungsten carbide bur created a surface rougher than the composite bur did. This result might be related to disintegration of composite bur in contact with enamel surface while the cutting edges of tungsten carbide bur remove a significant amount of enamel.

Thermal changes of the pulp chamber in different groups were not similar. The temperature of the pulp chamber increased significantly in composite bur and tungsten carbide bur groups while decreased significantly in Er:YAG laser group. This decrease in temperature was apparently related to the cooling air and water system in Er:YAG laser application. These results are consistent with earlier researches.[17,18,20] There is a controversy over thermal effect of tungsten carbide bur. Mank *et al*.[21] stated that in the absence of air or water cooling system, the temperature of the pulp chamber did not significantly increase while Ozer *et al*.[26] suggested low speed hand piece with air cooling, and Uysal *et al*.[4] showed a decrease in temperature by 5.36°C when cooling water was applied. These two later results are consistent with our result.

In the present study, it took 56.53 s for tungsten carbide bur and 37.85 s for composite bur to increase the temperature by 5.5°C. Since increased temperature by 5.5°C may lead to irreversible pulp tissue inflammation (in 40% of cases), it is suggested to apply air or water cooling system, or work intermittently when using tungsten carbide or composite burs.

The time consumed to remove adhesive residue from the enamel surface depends largely on the amount of remnant adhesive. In this study, the distribution of ARI scores for the experimental groups were broadly similar and the ARI score two was the most frequent score; hence, the groups were comparable. Although, no significant differences were observed between groups, tungsten carbide bur took shorter time than two other methods to remove adhesive residue. This might be related to having sharp cutting edges on this bur while composite bur works by means of abrasion. Er:YAG laser was the slowest.

CONCLUSION

1. SEM images showed that composite bur created the smoothest enamel surface while Er:YAG laser the roughest.
2. Tungsten carbide and composite burs generated significantly more heat compared to Er:YAG laser.
3. Temperature of the pulp chamber increased by 5.5°C in 56.36 and 37.86 s by tungsten carbide and composite burs, respectively.
4. Tungsten carbide bur was the fastest and Er:YAG laser the slowest devices to remove adhesive residue.

Regarding the results of the present study, composite bur with air or water cooling system, because of being less harmful to enamel and pulp tissue, is recommended to remove the residual adhesive following orthodontic bracket debonding.

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Figures and Tables

Table 1

Groups ARI score*	Composite bur	Tungsten carbide bur	Er:YAG
0	0	0	0
1	3	6	5
2	26	23	23
3	1	1	2

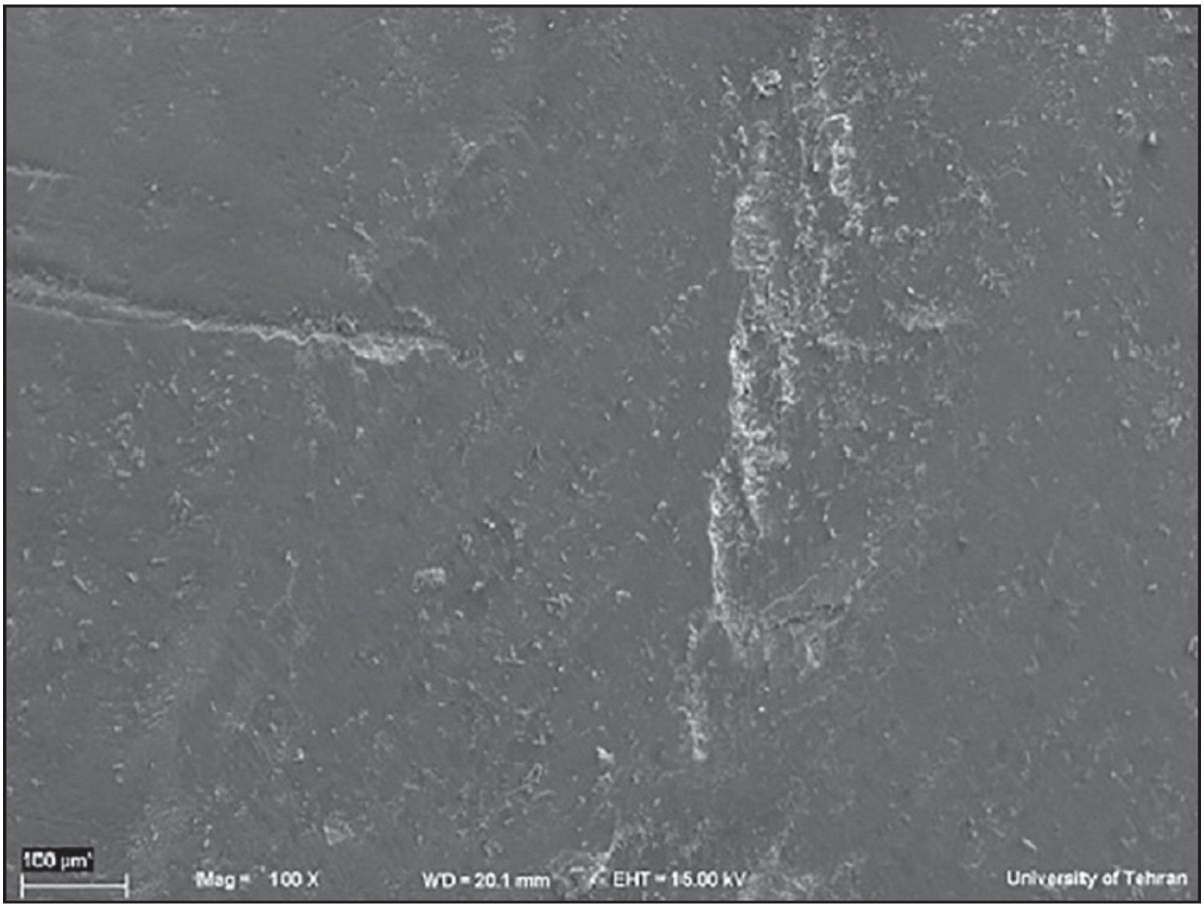
$\chi^2 = 1.75$; $P = 0.78$; Values are presented as number only. $P < 0.05$ indicates a significant result after Chi-square test; Er:YAG: Erbium-doped yttrium aluminum garnet; ARI: Adhesive remnant index, *ARI scores-0: No composite remains on tooth surface; 1: Less than 50% of the composite remains on tooth surface; 2: More than 50% of the composite remains on tooth surface; 3: All of the composite remains on tooth surface.

Distribution of ARI

Figure 1

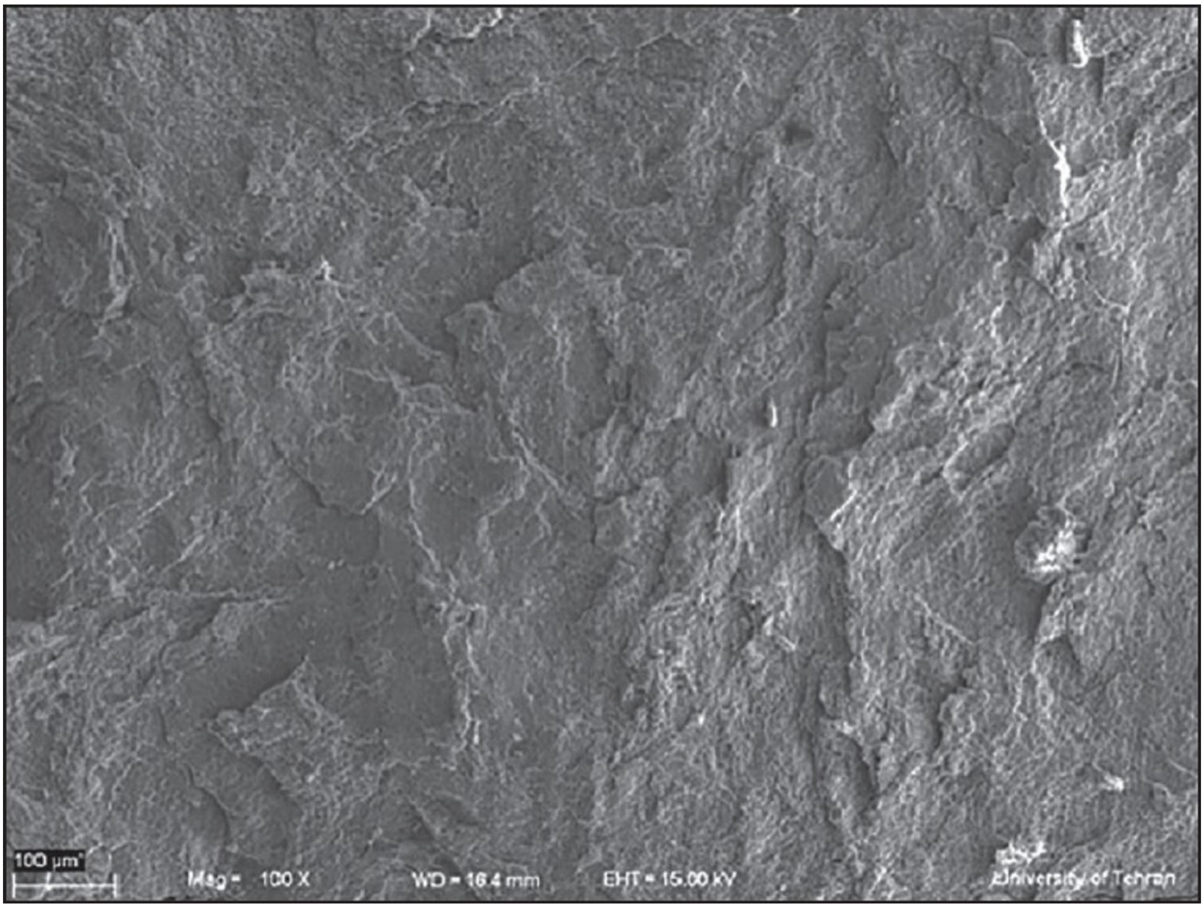
Scanning electron micrograph of a specimen after adhesive removal by composite bur (×100 magnification).

Figure 2



Scanning electron micrograph of a specimen after adhesive removal by tungsten carbide bur (×100 magnification).

Figure 3



Scanning electron micrograph of a specimen after adhesive removal by erbium-doped yttrium aluminum garnet laser (×100 magnification).

Table 2

Groups	N	Grade 0	Grade 1	Grade 2	Grade 3
Composite bur	30	23	7	0	0
Tungsten carbide bur	30	0	13	15	2
Er:YAG	30	0	0	0	30

Fisher exact test; $P < 0.001$; Values are presented as number only. $P < 0.05$ indicates a significant result after Fisher exact test; *Enamel damage index: Grade 0 is when the surface is smooth without any scratches; Grade 1 is when some scattered scratches are visible; Grade 2 is when the surface is rough with numerous deep scratches and some grooves; Grade 3 is when deep scratches and wide groves are visible with naked eyes; Er:YAG: Erbium-doped yttrium aluminium garnet.

Distribution of enamel damage index* following adhesive removal

Table 3

Groups	N	Mean ± SD	Minimum	Maximum
Composite bur	30	8.47±3.07	3	13.7
Tungsten carbide bur	30	8.60±3.01	2	14.0
Er:YAG	30	−3.60±1.82	−8	−0.9

ANOVA; $P < 0.001$; $P < 0.05$ indicates a significant result after analysis of variance; Values are presented as number and mean ± SD and minimum and maximum; SD: Standard deviation; Er:YAG: Erbium-doped yttrium aluminum garnet.

Thermal changes (°C)

Table 4

Groups*	N**	Mean ± SD	Minimum	Maximum
Composite bur	26	37.86±4.2	25	100
Tungsten carbide bur	26	56.53±4.35	25	105

ANOVA; $P = 0.004$; $P < 0.05$ indicates a significant result after analysis of variance; Values are presented as number and mean±SD and minimum and maximum; *No increase in pulp chamber temperature was seen in Er:YAG group; **Four cases of composite bur and 4 cases of tungsten carbide bur groups did not show increase in temperature of pulp chamber by 5.5 (°C); SD: Standard deviation; Er:YAG: Erbium-doped yttrium aluminum garnet.

The time spent (sec) that raised temperature of pulp cavity by 5.5 °C

Table 5

Groups	*N*	Mean ± SD	Minimum	Maximum
Composite bur	30	3.60±1.19	1	5
Tungsten carbide bur	30	2.93±1.11	1	5
Er:YAG	30	3.79±1.93	1	9

ANOVA; $P = 0.069$; $P < 0.05$ indicates a significant result after analysis of variance; Values are presented as number and mean ± SD and minimum and maximum; SD: Standard deviation; Er:YAG: Erbium-doped yttrium aluminum garnet.

Time consumed (min) to remove remnants of adhesive