Different modes of diode laser irradiation: effects on enamel surface and intrapulpal temperature at debonding

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Background: laser aided debonding of ceramic brackets has been proved to be effective in reducing enamel surface damages, though the optimal parameters of laser to be chose is in question. The aim of this study was to investigate the six different regimens of diode laser irradiation on enamel surface characteristics and intrapulpal temperature changes while debonding.

Material and Methods: 90 polycrystalline brackets were bonded to 90 intact extracted premolars. At debonding, teeth were divided into 6 groups (n = 15) and were subjected to the following regimen of diode laser irradiation; G1 = 2 W, continuous wave, G2 = 2.5 W, continuous wave, G3 = 3 W, continuous wave, G4 = 2 W, pulsed mode, G5 = 2.5 W, pulsed mode, G6 = 3 W, pulsed mode. After debonding, the adhesive remnant index, the lengths and frequency of enamel cracks were compared among the groups. 5 teeth out of 15 were randomly selected from each group to assess the intrapulpal temperature changes.

Results: The number of enamel cracks increased significantly in all the specimens after debonding. Enamel crack length increased significantly in all the study groups except G3 and G6. The increase in intrapulpal temperature was significantly below the benchmark of 5.5 °C for all the specimens. Significant difference was observed in adhesive remnant index scores among the groups and more than half of the teeth showed a score of 2.

Conclusion: Diode-laser irradiation in pulsed mode or continuous wave at given outputs (2, 2.5, 3 W) were not statistically different in regard to producing enamel surface damages or increasing intrapulpal temperature.

Key words: Ceramic brackets • continuous wave • diode laser • pulsed mode • temperature

Introduction

Today, increasing number of adult orthodontic patients and their demand for less visible appliances urged clinicians to vigorously promote the esthetic values. The invention of ceramic brackets in 1980s, as a big step toward a more pleasant orthodontic therapy, provided higher strength, more resistance to deformation and better color stability in comparison with the other tooth colored brackets. However the low fracture toughness and high bond strength of these brackets could impose complications at debonding. Enamel cracks, fracture or tear out are some instances. To avoid these adverse effects, several debonding techniques have been developed such as, electrothermal debonding, ultrasonic debonding and the use of specially designed instruments for mechanical debonding. Furthermore, lasers with different wavelength have been suggested to be used in bracket debonding since 1990. It is well documented that laser sources such as CO2, Er-YAG, Nd:YAG, diode laser ytterbium fiber lasers and Tm:YAP significantly reduce the debonding force which can lead to less enamel injuries.

Diode lasers, among all the lasers, are far the most suitable ones due to small size, cost-effectiveness and ease of operation. Diode laser are commonly available in wavelength of 810-980 nm which is safe to use adjacent to tooth structure. Our preliminary study indicated that debonding of ceramic brackets with diode laser (980 nm wavelength and 2.5 watt output) resulted in significantly less enamel crack and fracture compared with control group of conventional debonding. Also, the results,
showed a significant increase in the pulpal temperature, though lower than the critical threshold. These results encouraged the authors to perform another study for finding optimal parameters of diode laser to best ease debonding and least temperature rise. Therefore the present study was undertaken to investigate the effects of output of diode laser in 2 modes (continues and pulsed) on enamel surface and pulpal temperature.

Materials and Methods

This study was approved by ethical committee of Yazd University of Medical Sciences, Yazd, Iran with the reference number of IR.SSU.REC.1396.39 on Feb 2017.

Specimen selection

In this parallel lab trial study 90 carious-free human premolars extracted for orthodontic reasons were collected. All the samples were mounted in dental stone blocks to make reproducible position under different experimental situations. Teeth were stored in distilled water at room temperature.

Before the initiation of the experiment, the buccal surface of the all the teeth were cleaned and photographed using digital camera of stereomicroscope (Olympus, SZX16, Japan) with 23.5 times magnification. The length and number of pre-trial enamel cracks were recorded using the digital scale of camera.

Bracket bonding

The surface of enamel to be bonded was etched with a 37% phosphoric acid gel for 30 seconds, rinsed thoroughly with water for 20 seconds, and completely dried with oil/moisture free air spray until it appeared frosty white. After applying the Transbond XT prime to the enamel, polycrystalline ceramic brackets (Allure, GAC International Inc, Japan) were bonded on the center of the buccal surface using Transbond XT adhesive (3M unitek, USA) and light cured for 20 seconds.

To ensure complete polymerization teeth were stored in water at 37°C for more than 24 hours.

Study groups

Specimens were randomly divided into 6 groups of 15 teeth based on the diode laser regimen at debonding. G1, G2 and G3 were exposed to continuous diode laser with output of 2, 2.5 and 3 watt respectively. While in G4, G5 and G6 pulsed mode of diode laser with respectively the same output of 2, 2.5 and 3 watt and pulse duration of 30 µs was applied.

Laser-aided bracket debonding

Before mechanically debonding the brackets, diode laser (Fox, A.R.C, Germany, 980 nm) with specific parameters as mentioned beforehand was applied to each group’s teeth for 10 seconds (5 s from mesial and 5 s from distal). The tip of laser waveguide was positioned 5 mm to the bracket surface, the laser beam was delivered perpendicular to the bracket surface and it was moved with sweeping motion parallel to the bracket slot. Three seconds after the diode lasing, the brackets were removed using the manufacturer’s recommended instrument.

Intrapulpal temperature

From each group 5 teeth out of 15 were randomly selected to measure the temperature changes during laser debonding. Before bracket debonding, an access cavity on the lingual surface of each selected tooth was prepared by a long fissure bur and the remained pulpal tissue was removed and cleaned by using a spoon excavator and hypochlorite solution. To record the intrapulpal temperature, a k type thermocouple (CENTER 306-Thermometer, Centertek, Taiwan) with the accuracy of ± 0.3°C + 1°C equipped with a data logger system was positioned in the cavity to contact its sensor with the buccal wall of the cavity just below the bracket.

Data collection and analysis

After debonding process, buccal surface of the samples were carefully evaluated under stereoscopic magnifying at x 10 to record the adhesive remnant index (ARI) score established by Artun and Bergland, as follow: 0: no adhesive remaining on the tooth; 1: less than half of the adhesive remaining on the tooth; 2: more than half of the adhesive remaining on the tooth; 3: all the adhesive remaining on the tooth.

Next, the remnant adhesive on enamel surfaces were completely grounded by tungsten carbide bur and all the samples were again photographed under the exact same conditions of the first one to record the post-trial enamel crack length and frequency.

The data were entered into a computer using the SPSS version 16 software and analyzed by Wilcoxon signed-rank test, ANOVA, Kruskal Wallis and Fisher exact test considering a significant level of 0.05.

Results

Kruskal-wallis test indicated no significant between-group differences in enamel crack length and enamel crack frequency before bracket bonding which confirmed the homogeneity of the samples (P-value > 0.05).

No enamel fracture or bracket failure was observed during debonding of brackets in none of the groups. The mean length and frequency of cracks, mean differences, SD values and the result of Wilcoxon and Kruskal Wallis tests are given in table 1 and 2. The entire specimen showed a significant increase in the number of enamel cracks after bracket removal. Also, all groups except group 3 (p-value = 0.05) and 6 (p-value = 0.064) showed remarkably increase
in the length of enamel cracks after debonding. G1 (continuous wave, 2 watt) showed the highest increase in enamel frequency of 1.30 ± 1.22 and G3 (continuous wave, 3 watt) showed the least increase in enamel crack length 0.46 ± 0.74 mm, although these results were not statistically significant compared with other groups.

While laser irradiation, Temperature increase was significantly different between groups (ANOVA, P-value: 0.036). The post hoc multiple comparison Tuckey test revealed that this difference only between group 2 and 3 was significant (P-value: 0.02). However the most increase in intrapulpal temperature was recorded in G3 (3.39 ± 0.76°C) following by G6 (2.84 ± 0.40). This increase was significantly below the temperature threshold (5.5°C) required to cause pulpal damage. Table 3 illustrates the intrapulpal temperature in study groups.

In total, 65% of the debonded brackets had an ARI score of 2 and 3. The least frequency of the ARI score was of 0 seen in 12 teeth (13.3%). Fisher’s exact test showed that the differences were statistically significant (P < 0.001) Table 4 presents ARI data for the study groups.

### Discussion

This study used 90 human premolars to investigate the effects of diode laser-debonding on enamel surface and pulpal temperature. There are several studies assessing the application of different kinds of lasers like CO2, Nd-YAG, Er-YAG, TM-YAD and etc for facilitating the ceramic bracket removal. The selection of laser is based on certain factors such as clinical applicability, setup size, price and ease of operation 16-17. Nd-YAG and CO2 lasers are not commonly used due to large size and high costs. Erbium lasers are smaller but still expensive for daily use in

**Table 1: Frequency** of enamel cracks before bonding and after debonding

<table>
<thead>
<tr>
<th>groups</th>
<th>Before mean ± SD</th>
<th>After mean ± SD</th>
<th>Difference mean ± SD</th>
<th>P-valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.90 ± 1.07</td>
<td>2.20 ± 1.74</td>
<td>1.30 ± 1.22</td>
<td>0.007</td>
</tr>
<tr>
<td>G2</td>
<td>1.13 ± 1.18</td>
<td>1.78 ± 1.67</td>
<td>0.65 ± 1.03</td>
<td>0.008</td>
</tr>
<tr>
<td>G3</td>
<td>0.60 ± 0.91</td>
<td>1.86 ± 1.30</td>
<td>1.20 ± 1.20</td>
<td>0.004</td>
</tr>
<tr>
<td>G4</td>
<td>1.46 ± 1.35</td>
<td>2.46 ± 1.45</td>
<td>1 ± 1</td>
<td>0.004</td>
</tr>
<tr>
<td>G5</td>
<td>1.40 ± 0.91</td>
<td>1.80 ± 1.01</td>
<td>0.40 ± 0.63</td>
<td>0.034</td>
</tr>
<tr>
<td>G6</td>
<td>1.46 ± 1.40</td>
<td>2.66 ± 2.12</td>
<td>1.20 ± 1.27</td>
<td>0.010</td>
</tr>
</tbody>
</table>

P-valueb 0.05 < 0.05 <

a: Wilcoxon test  
b: Kruskal-Wallis test

**Table 2: length** of enamel cracks before bonding and after debonding in millimeter

<table>
<thead>
<tr>
<th>groups</th>
<th>Before mean ± SD</th>
<th>After mean ± SD</th>
<th>Difference mean ± SD</th>
<th>P-valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.77 ± 0.98</td>
<td>1.54 ± 1.05</td>
<td>0.83 ± 1.17</td>
<td>0.013</td>
</tr>
<tr>
<td>G2</td>
<td>1.12 ± 1.18</td>
<td>1.37 ± 1.14</td>
<td>0.25 ± 0.95</td>
<td>0.021</td>
</tr>
<tr>
<td>G3</td>
<td>1.13 ± 1.43</td>
<td>1.54 ± 1.10</td>
<td>0.46 ± 0.74</td>
<td>0.050</td>
</tr>
<tr>
<td>G4</td>
<td>0.87 ± 0.85</td>
<td>1.69 ± 0.93</td>
<td>0.83 ± 0.78</td>
<td>0.003</td>
</tr>
<tr>
<td>G5</td>
<td>0.99 ± 0.87</td>
<td>1.95 ± 1.36</td>
<td>0.95 ± 1.35</td>
<td>0.007</td>
</tr>
<tr>
<td>G6</td>
<td>1.87 ± 1.18</td>
<td>2.52 ± 1.35</td>
<td>0.65 ± 1.2</td>
<td>0.064</td>
</tr>
</tbody>
</table>

P-valueb 0.05 < 0.05 <

a Wilcoxon test  
b Kruskal-Wallis test

**Table 3: Temperature** changes during laser irradiation in Celsius degrees

<table>
<thead>
<tr>
<th>Temperature changes</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value(ANOVA)</td>
<td>0.036</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In total, 65% of the debonded brackets had an ARI score of 2 and 3. The least frequency of the ARI score was of 0 seen in 12 teeth (13.3%). Fisher’s exact test showed that the differences were statistically significant (P < 0.001) Table 4 presents ARI data for the study groups.

**Discussion**

This study used 90 human premolars to investigate the effects of diode laser-debonding on enamel surface and pulpal temperature. There are several studies assessing the application of different kinds of lasers like CO2, Nd-YAG, Er-YAG, TM-YAD and etc for facilitating the ceramic bracket removal. The selection of laser is based on certain factors such as clinical applicability, setup size, price and ease of operation 16-17. Nd-YAG and CO2 lasers are not commonly used due to large size and high costs. Erbium lasers are smaller but still expensive for daily use in
private offices. The choice of diode lasers are far more suitable as they are more compact, simpler to use and last longer. Concerning the mechanism of action of lasers several studies substantiate the fact that lasers can be used effectively to thermally soften the adhesive resin for ceramic bracket’s removal6, 18-19).

However Mundethu stated that “thermal softening” mechanism might lead to a large increase in bracket and enamel surface temperature. Therefore they proposed using a single pulse of Er:YAG laser with 600 mJ energy and 800 μs duration to achieve a rapid bracket debonding process based on “photo- ablation” mechanism which the increase in temperature is fast enough to cause bracket debonding before composite resin softening occurs20).

Similarly, Hayakawa supported applying high-peak power laser (Nd:YAG) as one pulse per location. They used different energy levels of 1, 2 and 3 J with pulse duration of 1.2 ms and concluded that high-peak power Nd:YAG laser at 2.0 J or more can effectively decrease the shear bond strength of composite resin without jeopardizing pulp vitality10).

Diode laser in wavelength of 810-980 nm (near infra red radiation) are highly absorbed by pigmented tissues with minimal interaction with hydroxyapatite and water. This property of diode makes it safe and well indicated to use adjacent to tooth structure21). It is worthwhile to mention that in this project, conventional method (mechanical-ly bracket debonding) as a control group was refused since in our previous study with the same experimental setups and in a same lab, we reached to this conclusion that conventional method in compared with laser-assisted method caused inferior results14). Therefore it was decided to conduct the present study to investigate the most favorable parameters of diode laser. The effects of 3 diode laser output powers in 2 modes of continuous and pulsed were investigated, hypothesizing that pulsed mode lasers may provide thermal relaxation for the tooth. Also, the enamel surface changes with each protocol of laser debonding were studied. Diode laser was selected for this study because of the compact size and relatively low price which makes them favorable in orthodontic practice14).

In the present study a significantly increase in enamel crack frequency was observed. Also all groups except G3 and G6 presented a statistically significant increase in enamel crack length. G3 and G6 which both irradiated with output of 3 watt, the former in continuous wave and the later with pulsed mode, showed an increase with borderline p-value of 0.05 and 0.064 respectively. This phenomenon could be explained by the higher output power compared with the other groups which might ease the bracket debonding more. Therefore relatively small increase in enamel crack length was seen. It might also simply be contributed to the small sample size of the study (90 teeth; 15 in each group).

These results are in agreement with the previous studies. Ahrari used ultra-pulsed CO2 laser with pulse duration of 500 μs and interval time of 2000 μs to assist the bracket debonding. They reported a significant increase in the number and length of the enamel cracks for both conventional and laser-assisted groups22).

A K-type thermocouple was used in this study to measure the intrapulpal temperature changes during laser. Analysis of variance indicated significant between-group differences which by the Tukey test it was revealed that this difference between G2 and G3 was significant. G3 (3watt, continuous wave) and G6 (3watt, pulsed mode) showed the highest increase in pulpal temperature which were 3.39 ± 0.76°C and 2.84 ± .040 respectively. In total pulsed mode groups (G4, G5 and G6) didn’t exhibit a distinct pattern of less increase in temperature compared with continuous wave groups (G1, G2 and G3) which probably undermine the hypothesis of thermal relaxation by pulsed mode lasers. However this increase was significantly below the threshold of 5.5°C23) and almost was in the same range of the similar studies. Nalbantgil reported that the temperature increased from

| Table 4: ARI score distribution |
|-------------------------------|-----------------|-----------------|-----------------|
|                               | 0               | 1               | 2               | 3               |
| **G1**                        | 2 (13.3%)       | 1 (6.7%)        | 10 (66.7%)      | 2 (13.3%)       |
| **G2**                        | 1 (6.7%)        | 4 (26.0%)       | 8 (53.3%)       | 2 (13.3%)       |
| **G3**                        | 3 (20%)         | 2 (13.3%)       | 7 (46.7%)       | 3 (20%)         |
| **G4**                        | 0               | 2 (13.3%)       | 10 (66.7%)      | 3 (20%)         |
| **G5**                        | 3 (20%)         | 1 (6.7%)        | 8 (53.3%)       | 3 (20%)         |
| **G6**                        | 3 (20%)         | 3 (20%)         | 6 (40%)         | 3 (20%)         |
| **Total**                     | 12 (13.3%)      | 13 (14.4%)      | 49 (54.4%)      | 16 (17.8%)      |

P-value (Fisher’s exact test) < 0.001
25°C to 26.27 ± 0.3°C, 27.79 ± 0.71°C, and 29.59 ± 0.48°C in the 3-, 6-, and 9-s of Er-YAG lasing, respectively. Obata et al reported that during debonding, super plus CO₂ irradiation raised the temperature for a 1.4°C at 2 watts and 2.1°C at 3 watts.⁷

ARI score is an indirect method of evaluating the probable risks of enamel damage. Bond failure at the adhesive-bracket interface has the advantage of protecting the enamel surface, but it requires meticulous grinding to remove the entire adhesive remnants on the tooth.³⁰ In this study 65% of the teeth had an ARI score of 2 or 3 which indicated a desirable cohesive failure. Mundethu reported that all their samples (20 human third molars) showed an ARI score of 3 after single-pulse irradiation with Er-YAG laser.³⁰ Ahhari noticed that the frequency of ARI score 0 in nonlased groups were 43.7 % while laser debonding decreased the percentage of ARI score 0 to 5%³⁰.

**Conclusion**
Based on the results of this study following conclusions were produced:

1- Diode-laser irradiation, although made the debonding process easier, it yet companied with some enamel damage and temperature rise.

2- When diode laser debonding, pulsed mode and continuous wave were not different in producing enamel cracks.

3- The rise in intrapulpal temperature, with any protocol used in this study, was extremely low.

### References


