Shear Bond Strength of Primary Teeth Dentin Irradiated with Different Erbium-doped Yttrium Aluminium Garnet Laser Energies and Scanning Electron Microscope Study of Dentin Morphology

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How to cite the article:

Abstract:
Background: Erbium-doped yttrium garnet laser (Er: YAG) laser for preparing dental surface alters dentin morphological characteristics which may interfere with bonding. This study aimed to evaluate the effect of different Er: YAG laser energy levels on shear bond strength (SBS) of composite resin to primary tooth dentin and to assess the morphological appearance of dentin by scanning electron microscope (SEM).

Materials and Methods: In this in vitro study, 48 primary molars were sectioned mesio-distally (96 samples). About 64 sound buccal or lingual surfaces were randomly divided into 4 groups of 16 samples. Superficial dentin of buccal or lingual surfaces were exposed and polished up to 600-grit of silicon carbide paper. Dentinal surfaces were irradiated with different Er: YAG laser energy levels of 100, 200, 300 mJ/10 Hz. Sixteen specimens were not irradiated to serve as control. The Single Bond adhesive was applied over the acid-etched dentinal surfaces for all tested groups and composite resin cylinders were bonded to the samples. Following thermocycling, SBS of composite resin to dentin were measured and statistical analyses were done using ANOVA and least significant difference tests. For morphological analysis, 32 specimens were examined by SEM.

Results: The mean SBS was 15.72 ± 4.05, 23.04 ± 2.81, 34.57 ± 9.63, and 38.39 ± 8.15 megapascals in control, 100, 200, and 300 mJ groups, respectively. There was no significant difference in SBS of 200 and 300 mJ laser energies. SEM images showed that etching after Er: YAG laser irradiation left no smear layer and a few scaly and irregular surfaces were observed, with the widening of dentinal tubules openings.

Conclusion: Power output of 200 and 300 mJ in primary tooth dentin preparation yielded highest bond strength but 200 mJ was safer and more effective.

Key words: Dentin, erbium-doped yttrium aluminum garnet laser, primary teeth, shear bond strength, scanning electron microscopy

Introduction
Advances in adhesive dentistry has led to the introduction of modern methods of surface preparation as laser to reach high bond strengths by increasing the surface roughness of dental hard tissues and restorative material.1-2 Shear bond strength (SBS) is the essential factor for long-term clinical success of esthetic restorations.1,3 Although the clinical efficacy of bond to enamel has been documented, further studies are required to assess the bond to dentin.4 There are some problems regarding the composite bond strength to dentine, including hydrated nature, variable, and complex composition of dentin, and interference with smear layer which needs to be removed or modified.4,5

In recent years, the use of erbium-doped yttrium aluminum garnet (Er: YAG) laser in pediatric dentistry has become popular because it could efficiently cut enamel and dentin with no pain, lesser noise and vibration.6

Current bonding systems have been produced to be used in the cavities prepared by conventional dental drill, but their efficacy is not known in the cavities prepared and decays removed by laser.3

Different studies have shown that Er: YAG laser can remove smear layer, open dentinal tubules and create a rough surface.3,6,8 Some studies have found that these properties have led to better etching techniques and adhesion of bonding material,9,12 but others have report the opposite results.8,3

Primary tooth dentin has a lower mineralization, higher organic material, and water content compared to permanent teeth. The density and thickness of dentinal tubules in 0.4-0.5 mm to pulp surface is lower;7,8,12 so, considering these morphological differences and heterogeneous composition, laser parameters should be set differently in primary teeth.3,6,8,12 We could find few studies on the effect of different strength of composite to primary teeth dentin; so, this study was designed to assess the effect of different energy levels of Er: YAG laser on the SBS of composite to primary teeth dentin and observing the effect of these different energy levels on dentin morphology by scanning electron microscope (SEM).
Materials and Methods

In this in vitro experimental study, a total of 48 first and second primary molars with sound buccal (B) and lingual (L) surfaces extracted within a 3 months period were gathered. After sectioning the teeth, 96 specimens were collected. All teeth were disinfected in 0.5% chloramine-T solution for one week and then were carefully cleaned with a rotary brush and water/pumice slurry. The teeth with caries, restorations, cracks, and other structural defects were excluded. To prevent dehydration, specimens were stored in distilled water.

For SBS test, 32 specimens were sectioned 2 mm beneath the cement-enamel junction and then they were divided into B and L halves in a mesiodistal direction using a fine diamond disk. Each specimen including a sound B or L surface of a primary molar was bonded in autopolymerizing acrylic resin using 2.5 × 3.5 cubic metallic mold.

The enamel of the specimens in the dentino-enamel junction was removed using a disc and cooling spray to expose the first layer of superficial dentin. Then, the dentinal surface of the specimens was polished using a water-cooled silicon carbide paper (SiC) with grit size of 320-400, until a uniform layer of peripheral dentin was created. To establish a standard smear layer another wet grinding was performed by a 600 grit SiC for 30 s. A piece of tape with a 3 mm central hole was placed on the surface of each dentin specimen to limit the irradiated surface area and dentin adhesive site.

The dentin specimens were randomly divided into following four groups (n = 16) according to the energy level of Er: YAG laser (Fotona, Fidelis PlusIII, Slovenia):

- **Group 1**: Without laser emission (control)
- **Group 2**: 100 mJ
- **Group 3**: 200 mJ
- **Group 4**: 300 mJ

The parameters of laser irradiation were as follows: Wavelength: 2.94 μm; frequency: 10 Hz; the distance between laser source to specimens: 20 mm; pulse duration: 0.1 ms. According to the manufacturer’s instructions, the device was set in micro-short pulse mode. The laser was used for 12.5 s. The hand piece was R02-c-919, which was used in non-contact mode under 8 ml/min water spray.

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The dentin surfaces in four groups were etched with 37% phosphoric acid gel for 10 s. and rinsed for 20 s.

According to the manufacturer’s instructions, two layers of bonding agent (Adper single bond, 3MESPE, USA) were applied on the etched surfaces and light cured for 20 s (Arialex, Apadana Tak, Iran) with output of 450 mW/cm². Using a transparent matrix rod (Nelaton) with an inner diameter of 2 mm, an approximately 2 mm long composite resin (Z-250, 3M/ESPE) was bonded to each dentin specimen and cured for 40 s. After the Nelaton was cut by a blade, the composite rod was cured again for 40 s. The specimens were then stored in 37°C distilled water for 24 h, and then thermocycled for 500 cycles between 5°C ± 2°C and 55°C ± 2°C water baths with 30 s dwell time and 15 s transfer time between baths. Specimens were transferred to laboratory for SBS test.

SBS was measured in megapascals (MPa) using a universal testing machine (Zwick/Roell Z050, Germany) with cross-head speed of 0.5 mm/min and a 50 KN load cell until fracture of the composite-tooth interface.

Thirty two dentin specimens were prepared by the same techniques for assessment of the morphological changes on dentin surfaces due to pre-treatment with different laser energy levels and subsequent acid etching. All specimens were coated by gold and were examined by Field Emission–SEM (HITACHI S4160, Japan) at ×500 ×5000 magnification. The morphological characteristics of the primary dentinal surface were assessed. Statistical analysis was performed by SPSS 17.

**Results**

The values of SBS (mean ± standard deviation) in MPa are shown in Table 1. ANOVA test revealed that there was a statistically significant difference among the groups irradiated with different energy levels of Er: YAG laser (P < 0.001). Pair-wise comparisons of mean SBS values with least significant difference test (Table 2) showed that laser treated groups demonstrated significantly higher mean bond strength values than the control group (P < 0.001). Although The increase of Er: YAG laser energy level caused an increase in resin composite bond strength to dentin (P < 0.001), there was no significant difference in the means of SBS of groups with 200 mJ

### Table 1: Shear bond strength (in MPa) in study groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number</th>
<th>Energy level</th>
<th>Mean±SD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>No laser</td>
<td>15.72±4.05</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>100 mJ</td>
<td>23.04±2.81</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>200 mJ</td>
<td>34.57±9.63</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>300 mJ</td>
<td>38.39±8.15</td>
</tr>
</tbody>
</table>

*SD: Standard deviation, MPa: Megapascals

### Table 2: Pair-wise comparisons of mean bond strength values in study groups

<table>
<thead>
<tr>
<th>Comparisons between groups</th>
<th>Absolute value of the mean differences (MPa)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control with 100 mJ</td>
<td>7.31</td>
<td>0.003</td>
</tr>
<tr>
<td>200 mJ</td>
<td>18.84</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>300 mJ</td>
<td>22.67</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>100 mJ with 200 mJ</td>
<td>11.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>300 mJ</td>
<td>15.35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>200 mJ with 300 mJ</td>
<td>3.82</td>
<td>0.115</td>
</tr>
</tbody>
</table>

*Pair-wise comparisons with least significant difference test. MPa: Megapascals
and 300 mJ laser energy levels \((P > 0.05)\). The analysis of the SEM micrographs of control group revealed an even surface with demineralized peritubular dentin and different sizes of open dentinal tubules, which were occasionally covered with smear plug. The dentinal surfaces were covered by a smear layer and irregular debris in some areas (Figure 1).

In the laser groups, dentin surface appeared more rough and scaly and the openings of tubules were more widened than control group. Smear layer was completely removed and there was no smear plug in the tubules.

By increasing the energy level of laser with subsequent acid etching, the width, and number of openings in dentinal tubules was increased (Figure 2a and b). There was no obvious crack or melting of the dentin in groups irradiated with 100 and 200 mJ lasers, but at 300 mJ energy level, more uneven surface, partial melting, and cracks was seen (Figure 3).

**Discussion**

Recent developments in the use of laser in dentistry have raised many questions about the type of laser, its characteristics and parameters for creation of an appropriate bond to dental tissue.

Comparing permanent dentin, primary dentin contains more organic material and water content, and its dentinal tubules are more irregular, and the water content in inter-tubular dentin is higher than intra-tubular dentin,\(^6,12\) so using a laser with similar power will remove higher amount of tissue in primary teeth. Thus, the parameters used in primary teeth should be lower than those used in permanent teeth.

In this study, SBS test was used, because it seems that shear stresses are the most important forces in the *in vivo* bond failures of restorative materials. It has been shown that SBS test is a reliable method for predicting the clinical efficacy of restoration.\(^9\)

The results of this study showed that laser irradiation establishes an adhesion pattern that will improve the bonding process which was consistent with the results of Hossain *et al.*,\(^13\) Visuri *et al.*,\(^10\) and Hibst *et al.*,\(^16\) Wanderly *et al.*,\(^8\) and Mahmoudian *et al.*.\(^11\) In the study conducted by Sung EC, despite using a different type of laser (Er, Cr: YSGG), the overall result was in agreement with the results of the current study.\(^14\)

Some researches such as Armengol *et al.*,\(^17\) Kataumi *et al.*,\(^18\) and Burnett *et al.*\(^19\) found no difference between specimens irradiated be Er: YAG laser and control group in terms of bond strength.

Inconsistent with the current study, Sakakibara,\(^20\) Dunn *et al.*,\(^7\) and Ceballo *et al.*\(^21\) have found lower SBS after laser irradiation. They proposed that laser irradiation creates a layer of rather denatured collagen fibers with poorly adhesion to dentinal surface which lacks peri-fibrillar spaces and may limit the resin penetration to subsurface inter-tubular dentin and weaken the formation of hybrid layer.\(^21\) It seems that phosphoric acid removes the modified layer formed by laser radiation. Gurgan *et al.*,\(^9\) Shirani *et al.*,\(^1\) Carvalho *et al.*,\(^22\) and Yung *et al.*\(^23\) found that acid etching of laser-irradiated dentin significantly improves the efficacy of total-etch adhesive system. Therefore, the increase
in bond strength of total-etch adhesive system (single bond) used in this study can be explained.

The effect of Er: YAG laser on dentinal surface is dependent on several factors such as output energy, frequency, pulse duration, focal distance, duration of irradiation, and water cooling, and it seems that the differences between studies are raised from different laser devices, different parameters of lasers, and different adhesive materials.

The results of the present study also showed that increasing laser energy will increase the SBS which was in agreement with the results of Osman et al. study on permanent teeth. Although we could not find a significant difference between 200 and 300 mJ energy levels, which is probably due to superficial changes of dentin after ablation by laser. Therefore, SEM analysis may help select the most effective and appropriate laser energy for preparation of dentinal surfaces.

In SEM micrographs of the laser-irradiated specimens, dentinal surface was free from smear layer and contained open dentinal tubules, but in the control group, some areas were covered by smear layer and some tubules did not open even after acid etching which was consistent with the results of many previous studies. By increasing the energy level of laser from 100 to 300 mJ, the surface roughness was increased, but the irregularities were decreased after acid etching and a uniform surface was formed and scaly areas were observed in some parts. It seems that phosphoric acid widens the openings of the tubules by removing the peri-tubular dentin. Therefore, funnel-shaped resin tags will be formed constituting a small part of the bond, but deeply penetrate the dentin. The increase in the size of the base of tags can lead to the increase in SBS which is in agreement with the results of the present study.

The SEM micrographs show a more destructive pattern for 300 mJ energy in dentinal surface of primary teeth, because we observed areas of melting and cracks, so it can be concluded that 200 mJ energy level is more appropriate than 300 mJ for the preparation of the dentinal surface of primary teeth, but considering the appropriate SBS in both of them, more studies are required to rule out 300 mJ as an appropriate energy level.

**Conclusion**

According to the results of the current study, it can be concluded that using Er: YAG laser with 200 and 300 mJ energy levels creates rough and uneven dentinal surface and removes smear layer and eventually increases SBS of composite to dentin of primary teeth, and it seems that 200 mJ energy level is more appropriate and safer for cutting and preparation of dentinal surface in primary teeth.

**Acknowledgments**

The authors thank Mr. Hooman Sabarou for his assistance in SEM observation. The authors wish to thank the Special Laboratory of dental research center of Tehran University of medical science who supplied the universal testing machine for shear bond strength test.

**References**


