Surface analysis of Erbium:YAG laser etching vs. acid-etched surface

ESEM observations in vitro study

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Summary

The aim of this study was to compare the effect of conventional acid etching with 37 percent phosphoric acid and an Er:YAG laser (non-contact mode) on surface changes in enamel.

Materials and methods

A total of 50 non-carious extracted human teeth were collected for the study. The teeth were divided into five groups wherein one set of teeth was acid etched for 30 seconds with 37 percent phosphoric acid and four groups were laser-ablated with an energy output of 50, 75, 100 and 150 mJ using an Er:YAG (2,940 nm wavelength) laser in non-contact mode. Micro-morphological effects were evaluated using an environmental scanning electron microscope (ESEM) for change in the structure of enamel.
The following observations were made: a comparison between acid-etching and laser treatment effects on tooth surface and smear layer for each group.

The ESEM evaluation showed that increasing the energy parameters showed a difference in the surface morphology of enamel from roughening to an etching-like micro-roughened pattern. Certain laser-treated teeth showed better micro-retentive features as compared to acid-etching.

Laser-treatment for providing a micro-retentive surface is a viable option that can be chosen. The Er:YAG laser energy levels that provide a comparable effect to acid-etching were also noted.

Hard-tissue lasers were introduced in dentistry nearly 20 years ago and a number of wavelengths have been tried and experimented upon for ablation of hard tissue, including enamel, dentin, cementum and bone. Laser delivery devices today have a number of parameters that can be modified by the clinician to obtain the desired results.

These include minor variables such as water and air, and major variables such as pulse mode, frequency and energy output.

With respect to pulse duration (the duration of a pulse) there are five options available, namely, very long pulse (VLP = 1,000 µs), long pulse (LP = 600 µs), short pulse (SP = 300 µs), very short pulse (VSP = 100 µs) and super short pulse (SSP = 50 µs). Also, frequency (the number of pulses per second) can be modified.

Energy output can also be varied depending upon a requirement of high or low energy levels. And also the power, which is a product of the energy output and frequency changes. It has been shown through a number of studies that the Er:YAG laser is an effective tool in cavity preparation etching and removal of caries from enamel and dentin.

In the numerous hard-tissue applications that lasers have been used for, it has been suggested that lasers cause a surface etching effect that is comparable to conventional acid etching.

This study aimed to analyze the changes in the ultrastructure of human enamel resulting from simulated cavity preparation by an Er:YAG laser, and to investigate the optimal parameters of that laser for ablating enamel for etching with a VSP and variable energy outputs (EO), but repetition rates (RPR) were kept constant and compared with the surface characteristic of an acid-etched surface.

Selection of samples

A total of 50 non-curious extracted maxillary human premolars were collected for the study. The teeth were washed in normal saline and gross calculus was removed using an ultrasonic scaler.
The teeth were stored in normal saline at room temperature until treated.

**Preparation of samples**

The cervical third of the buccal surface of each tooth was subjected to 15 seconds with an Er:YAG laser (Fotona Fidelis III Plus, Fotona d.d., Slovenia) at a 2,940 nm wavelength. A circular area of 2 mm in diameter (± 0.25 mm) was prepared using the laser in non-contact mode at a distance of approximately 7 mm from the tooth surface, and set at different energy parameters.

Keeping the frequency constant at 15 Hz, the energy output was varied from 50 mJ, 75 mJ, 100 mJ and 150 mJ. The power reading on the laser device was also increased accordingly. The water and air were kept constant at a value of six each. Ten samples were also etched with the conventional method of 37 percent phosphoric acid (3M ESPE, USA) for a period of 15 seconds. Following preparation of the samples with the prescribed parameters (Table 1) the teeth were subjected to ESEM analysis.

**ESEM evaluation**

Micromorphological effects were evaluated on enamel using an ESEM at a magnification of 100x and 2,000x, wherein we noted the effects of the laser on the enamel surface and smear layer for each setting.

Comparison between the laser-etched and 37 percent phosphoric acid-etched samples, and the ideal parameters for laser etching compared to conventional acid etching.

The advantage of the ESEM over the scanning electron microscope (SEM) is that the sample does not have to go through any processing; it can directly be placed into the microscope, thereby avoiding drying of the specimens during processing.

**Results**

The effects of the laser application on the enamel as observed with the ESEM were as follows.

**50 mJ**

A definite change in the surface of the enamel was noted at low power magnification (100x) as compared to the adjacent sound enamel. However, at a higher power magnification, the circular laser-treated area showed only a superficial roughness without the presence of a micro-retentive surface. (Fig. 1)

**75 mJ**

The circular path followed by the laser beam was clearly visible on the 100x magnification. Slot-type pattern of enamel ablation is seen in the 2,000x magnification indicating selective ablation of the enamel prisms occurring over the lased surface. The lased surface showed a definite micro-retentive surface with presence of elevations and depressions (Fig. 2).

**100 mJ**

Lower magnification showed the superficial
layer of enamel that melted and flowed in the direction of the laser beam. Higher magnification revealed the melting and partial recrystallization of the enamel prisms (Fig. 3).

150 mJ

When lased at 150 mJ, there was a saucer-like cavitation seen on the surface. Higher magnification showed molten and partially coalesced structures instead of the prismatic pattern of enamel, and a number of microcracks were also noted on the laser treated surface (Fig. 4).

37 percent phosphoric acid-etched surface

The acid-etched surface seen at a high power magnification clearly showed the presence of the key-hole pattern of enamel with a type III etching pattern. This showed a uniform micro-retentive surface over the etched area (Fig. 5).

Discussion

An evaluation of all the laser-treated groups revealed that the lased surfaces were free of any smear layer, indicating a good surface for bonding.10 However, the morphology of the lased enamel showed a large variation as the energy output was increased.

Excessive energy parameters did not give the same results in all the samples because of the presence of induced alterations resulting from the thermal effect.

Higher energy values were shown to change the structure of the enamel prisms. The changes in the inherent structure of the enamel prism followed this order: microroughness, micro-retentive areas, reorganization and recrystallization of enamel prisms and microcracks.

A micro-roughened surface was observed at a low energy output level of 50 mJ, however, the depth of the roughened areas seemed lesser as compared to the higher energy output of 75 mJ.

The ultra-structural appearance of enamel lased at 75 mJ was similar to that of conventionally etched enamel with 37 percent phosphoric acid. However, the etched surface showed a non-specific, mixed-type pattern of the rods and prisms as opposed to a uniform type III pattern seen with an acid-etched surface.11,12 Clinically, the advantage of laser etching over a conventional bur is that a debris-free, smear-free and oil-free surface is obtained.

The Er:YAG laser has also been shown to have anti-bacterial properties.13 The taste of phosphoric acid may also not be well accepted by the patients, hence laser etching would be a better option.

Conclusion

Through this study we have concluded that lasers definitely can be used as an alternative to conventional procedures. We concluded that the correct parameter of energy level has to be chosen to get the desired result for bonding procedures. We also inferred that 75 mJ of energy output with 15 mJ frequency provided a micro-retentive surface that was comparable to a 37 percent phosphoric acid-etched surface.

These results are based on the surface changes that have been seen on the enamel only and may not be indicative of the bonding ability of the lased surface to composite resins. Hence, studies should be carried out to compare the bond strengths of the
lased and acid-etched surfaces to validate the etching effect of the Erbium:YAG laser.

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**References**


**Table 1** Table showing groups and parameters used for each group.

<table>
<thead>
<tr>
<th>Groups (n=10)</th>
<th>Energy output (mJ)</th>
<th>Frequency (Hz)</th>
<th>Power (W)</th>
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<tbody>
<tr>
<td>I</td>
<td>50</td>
<td>15</td>
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<tr>
<td>II</td>
<td>75</td>
<td>15</td>
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</tr>
<tr>
<td>III</td>
<td>100</td>
<td>15</td>
<td>1.50</td>
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<tr>
<td>IV</td>
<td>150</td>
<td>15</td>
<td>2.25</td>
</tr>
<tr>
<td>V</td>
<td>37% phosphoric acid etched surface</td>
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**Fig. 5** High power magnification (2,000x) image of 37 percent phosphoric acid-etched surface showing type III etching pattern.

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