Surface analysis of Erbium:YAG laser etching v/s acid etched surface

ESEM observations *in vitro* study

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_Summary

Aim

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

_Materials & 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 % phosphoric acid and four groups were laser-ablated with an energy output of 50, 75, 100 and 150 mJ respectively using Er:YAG (2,940 nm wavelength) Laser in non-contact mode. Micromorphological effects were evaluated using an ESEM for change in the structure of enamel.

_Results

Following observations were made: Comparison between acid-etching & Laser treatment on the Effects on tooth surface and smear layer for each group.

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

_Conclusion

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.

_Introduction

Hard tissue lasers have been introduced in dentistry since almost 20 years and a number of wavelengths have been tried and experimented upon for ablation of hard tissue including enamel, dentin, cementum and bone.[1–4] Lasers delivery devices today have a number of parameters that can be modified

Fig. 1a_ Low power magnification (100x) image of enamel surface lased at 50 mJ and 15 Hz showing definite surface changes.
Fig. 1b_ High power magnification (2000x) image showing micro-roughened surface.
Fig. 2a_ Low power magnification (100x) image of enamel surface lased at 75 mJ and 15 Hz showing circular path followed by the laser beam.

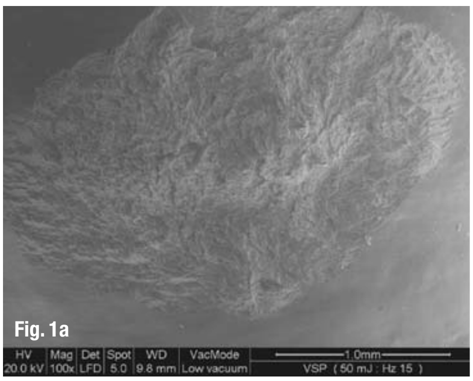


Fig. 1a

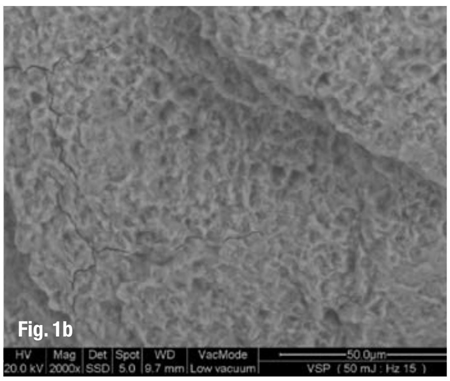


Fig. 1b

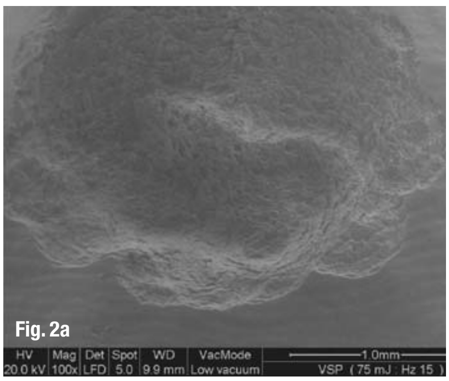
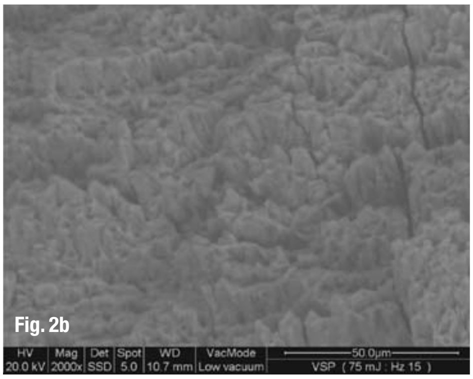
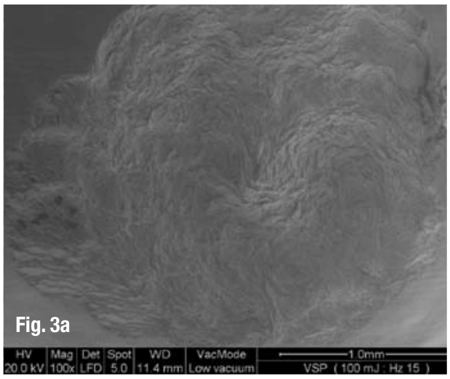


Fig. 2a





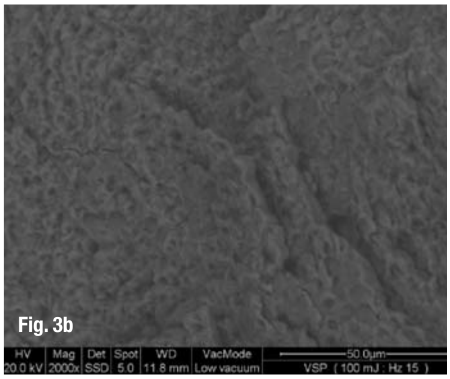


Fig. 2b_High power magnification (2,000x) image showing micro-retentive surface.

Fig. 3a_Low power magnification (100x) image of enamel surface lased at 100 mJ and 15 Hz showing surface melting.

Fig. 3b_High power magnification (2,000x) image showing melting and partial recrystallization of the enamel prisms.

by the clinician to obtain the desired results; these include minor variables like water and air; and major variables like Pulse mode, Frequency & Energy output.

With respect to pulse duration i.e. duration of a pulse there are five options available namely Very Long Pulse (1,000 µs), Long Pulse (600 µs), Short Pulse (300 µs), Very Short Pulse (100 µs), Super Short Pulse (50 µs). Also frequency (i.e. number of pulses per second) can be modified. Energy output can also be varied depending upon a requirement of high or low energy levels. The Power; which is a product of the energy output and frequency changes accordingly. 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.[5–9]

In the numerous hard tissue applications that lasers have been used for, lasers have been suggested to cause a surface etching effect which has been 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 (Very Short Pulse); variable energy outputs (EO) but Repetition Rates (RPR) kept constant and compare it with the surface characteristic of an acid-etched surface.

_Materials and methods

Selection of Samples

A total of fifty non-carious 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 3rd of buccal surface of each tooth was subjected to 15 seconds with an Er:YAG (Fotona Fidelis III Plus, Fotona d.d., Slovenia, EU) of 2,940 nm wavelength. A circular area of 2 mm diameter (± 0.25 mm) was prepared using the laser in non-contact mode at a distance of approximately 7mm from the tooth surface; set at different energy parameters. Keeping the Frequency constant at 15 Hz; the energy output was varied at 50 mJ, 75 mJ, 100 mJ and 150 mJ respectively. The Power reading on the Laser Device 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 % phosphoric acid (3M ESPE, USA) etching 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 Environment Scanning Electron Microscope (ESEM) at a magnification of 100x and 2,000x; wherein we noted the Effects of the laser on Enamel Surface and Smear Layer for each setting.

Comparison amongst the difference in laser etched and 37 % phosphoric acid etched samples and the ideal parameters for laser etching as compared to conventional acid etching.

The advantage of the ESEM over the Scanning Electron Microscope (SEM) being 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

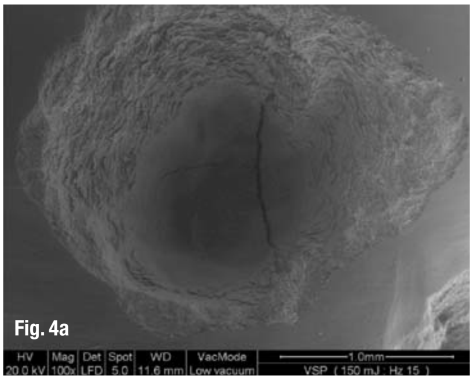


Fig. 4a

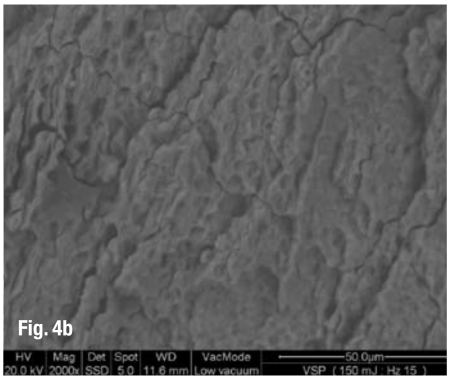


Fig. 4b

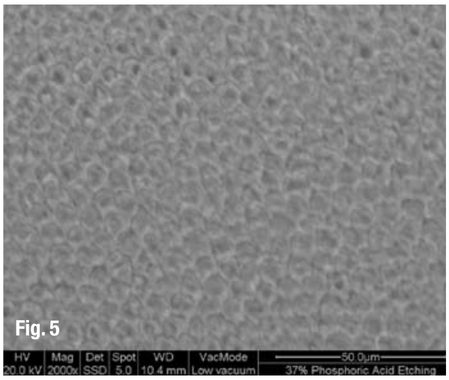


Fig. 5

Fig. 4 a_Low power magnification (100x) image of enamel surface lased at 150 mJ and 15 Hz showing saucer-like cavitation.

Fig 4 b_High power magnification (2,000x) image showing partially coalesced structure and presence of microcracks.

Fig. 5_High power magnification (2,000x) image of 37 % phosphoric acid etched surface showing type III etching pattern.

the presence of a micro-retentive surface. (Fig.1)

75 mJ

The circular path followed by the laser beam is 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 shows a definite micro-retentive surface with presence of elevations and depressions (Fig. 2).

100 mJ

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

150 mJ

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

37 % phosphoric acid etched surface

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

Groups (n=10)	Energy output (mJ)	Frequency (Hz)	Power (W)
I	50	15	0.75
II	75	15	1.10
III	100	15	1.50
IV	150	15	2.25
V	37% phosphoric acid etched surface		

Tab. 1_Table showing groups and parameters used for each group.

_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 be change the structure of the enamel prisms. The changes in the inherent structure of the enamel prism followed this order—Microroughness, Microretentive 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 % 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 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 a correct parameter of energy level has to be chosen to get the desired result for bonding procedures. We also inferred that 75 mJ Energy output with 15 mJ frequency provided a micro-retentive surface that was comparable to a 37 % 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 have to 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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_contact laser

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