EFFECT OF ER:YAG LASER IRRADIATION ON ENAMEL CARIES PREVENTION

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ABSTRACT

Background and Aim: The aim of this study was to examine the effect of Er:YAG laser irradiation on caries-like lesions in a simulated caries model.

Materials and Methods: Twenty extracted human non-carious molar teeth were selected. The teeth were covered with nail varnish, leaving two windows (approximately 4mm×2mm) on both the buccal and lingual surfaces at the middle third of the crown. The windows were randomly assigned to the four groups, which were no-treatment (G1), Er:YAG laser (KaVo KEY Laser 3, KaVo Dental GmbH) irradiation alone (G2), acidulated phosphorus fluoride (APF) gel (Sultan/Topex Neutral Ph Gel, Sultan Dental Products Ltd) treatment alone (G3) and Er:YAG laser irradiation before APF gel treatment (G4). A two-day pH-cycling was performed, with an 18-hour demineralization followed by a 6-hour remineralization. Sections of 120±20 μm in thickness were obtained from each window. Mean lesion depth was measured using polarized light microscope. Results were statistically analyzed by using Kruskal-Wallis and Mann-Whitney U tests.

Results: Mean lesion depths were 134±32 micrometers for group G1, 90±18 μm for group G2, 109±25 μm for group G3, and 74±23 μm for group G4. Mean lesion depths of all treatment groups were significantly less than those for the matched no-treatment group (p<0.05). Er:YAG laser irradiation before APF gel treatment significantly reduced lesion depth compared with the no-treatment and APF gel treatment alone (p<0.05).

Conclusion: Er:YAG laser irradiation in combination with fluoride treatment was improved resistance to enamel dissolution and reduced the mean lesion depth.

Key words: Caries, Enamel, ER:YAG laser, Prevention

Submitted for Publication: 10.31.2012
Accepted for Publication: 11.29.2012
INTRODUCTION

Dental caries is reported to be the most common chronic disease especially in the early childhood. Preventive non-invasive modalities for this complex multifactorial disease conventionally include use of fluoride products with different application methods, regulation of dietary habits, professional plaque removal and oral hygiene techniques. In this context, fluoride is the most widely applied method for caries prevention that can enhance the subsurface remineralization of carious enamel, resulting in arrestment or reversal of caries lesions and inhibit the demineralization during the bacterially generated acid challenge. High-intensity lasers have recently been investigated as an alternative for caries prevention to enhance the enamel’s resistance to acid. The effectiveness of laser irradiation on tooth surface as a preventive treatment for caries has been related to the interaction of light with some of the enamel compounds. Since enamel is 85% by volume carbonated hydroxyapatite, with 12% water and 3% protein and lipid by volume, the use of wavelengths highly absorbed by water and hydroxyapatite together is expected to generate thermal changes in enamel which may be able to alter its structure chemically and/or morphologically. The erbium-doped:Yttrium–aluminum–garnet (Er:YAG) laser, which works at a wavelength of 2.94 μm, has been reported to ablate dental hard tissues due to its high absorbability in water and hydroxyapatite. It is reported that, laser application is supposed not to ablate the surface, but to change the enamel morphologically or chemically for the preventive treatment of dental caries.

Although the preventive effect of laser irradiation on enamel is described, the benefit from laser irradiation when combined with fluoride is not clearly established. Therefore, the aim of this study was to evaluate the increase of prevention against caries-like lesions on enamel when irradiated with Er:YAG laser combined with or without topical application of fluoride.

MATERIALS AND METHODS

Preparation of the samples:

Twenty freshly extracted human non-carious molar teeth, which determined using a dental microscope at x10 magnification (OMI® pico, Carl Zeiss, Oberkochen, Germany), were collected and immediately stored in 10% formol solution. Teeth with stains or cracks, observed under the microscope, were discarded. The teeth were covered with nail varnish, leaving two windows (4mm×2mm) on both the buccal and lingual surfaces at the middle third of the crown. The windows were randomly assigned into the four experimental groups by using randomized block design” (RBD). RBD divides the group of experimental units into "n" homogeneous groups of size t. These homogeneous groups are called blocks. The treatments are then randomly assigned to the experimental units in each block - one treatment to a unit in each block.

Surface treatments:

The surface treatments were performed under the following conditions: G1 (group 1), no-treatment; G2 (group 2), Er:YAG laser irradiation alone; G3 (group 3), acidulated phosphate fluoride (APF) gel application alone; and, G4 (group 4), Er:YAG laser irradiation combined with APF gel application. The samples from the experimental groups G2 and G4 were irradiated with Er:YAG laser (KaVo KEY Laser 3, KaVo Dental GmbH), emitting photons at a wavelength of 2.94 μm. The laser unit was used with low-fluence irradiation at 100 mJ with 2 pps (pulse per second), and 1.0 mm spot size. The tip was positioned 1 mm from the enamel surface (focused mode).

The samples from groups G3 and G4 were treated with APF gel (Topex® APF Fluoride Gels, Sultan Dental Products Ltd, Englewood, NJ, USA). In the G4, surface treatments with APF gel were performed after the laser application.

pH cycling:

After the surface treatments each tooth was cut into two halves longitudinally (disto-mesial) by cutting with a low speed saw (IsoMet® Low Speed Saw, Buehler®, Illinois, USA). The cut surfaces were covered with nail varnish and dried for 24 hours. A two-day pH-cycling was performed, with an 18-hour demineralization followed by a 6-hour remineralization. The demineralization solution at pH 4.5 contained 0.05 M acetic acid, 2.2 mM calcium, and 2.2 mM phosphate ions. The remineralization solution at pH 7.0 contained 0.15 M potassium chloride, 1.5 mM calcium, and 0.9 mM phosphate ions. A 5 min wash in the deionized and distilled water was done between the demineralization and remineralization phases and at the end of the process. Both demineralization and remineralization solutions were changed daily.

Evaluation of the surfaces:

The samples were embedded in epoxy resin with the cut face exposed. Two sections of 120±20 μm in thickness were obtained from each window by using a microtome.
(Isomet 5000, Buehler, Illinois, USA). Lesion depths of the demineralized surfaces were measured by using a polarized light microscope (LEICA DMLA, Wetzlar, Germany) at x100 magnification with an ocular micrometer. Kruskal-Wallis and Mann-Whitney U tests were used for evaluation of the treatment effects. Bonferroni correction was chosen for evaluation of the statistical significance of multiple comparisons between the four experimental group (0.05/number of comparisons). A usual alpha level of 0.05 was used to determine the statistical significance of the results.

RESULTS
The means of lesion depths and standard deviations of the four groups are listed in Table 1. Mean lesion depths (±standard deviation) were 134±32 micrometers for Group 1, 90±18 μm for Group 2, 109±25 μm for Group 3, and 74±23 μm for Group 4. Significant differences were found between the four experimental groups (p<0.05, Kruskal-Wallis).

There were statistically significant differences between Group 1 and 2, Group 1 and 3, Group 1 and 4 and Group 2 and 4 according to the multiple comparison with Bonferroni corrections (p<0.05/6= 0.0083).

Mean lesion depths of all treatment groups were significantly less than those for the matched control group (p<0.05, Mann-Whitney U). Er:YAG laser irradiation before APF gel treatment significantly reduced lesion depth compared with APF gel treatment alone (p<0.05). However, there was statistically no difference between Er:YAG laser irradiation alone and Er:YAG laser irradiation combined with APF gel application (p>0.05).

DISCUSSION
It has been recently shown that, hard tissue applications with lasers may not only limited to polymerization of visible light–cured preventive and restorative materials, tooth whitening procedures and cavity preparations for restoration placement, but may also include the laser applications for caries prevention and dentin hypersensitivity.20-21 It has been reported that lasers improve enamel's resistance to dissolution, enhance microhardness, and lessen in vitro caries formation and progression.22-23 Sub-ablative parameters of irradiation have been suggested to obtain caries prevention by using Er:YAG laser without ablating the enamel surface, because higher fluences could lead to enamel ablation and also induce a greater mineral loss during an acid challenge.24 While some researchers claimed that lower energy densities should not be able to increase the surface up to 300°C–450°C, and consequently less soluble compounds would not be formed,17 others argued that enamel irradiation with low fluences can reach the surface temperatues high enough to induce chemical changes in enamel.9 The ablation thresholds of ER:YAG laser was determined by many authors using sub-ablative laser parameters. Fried et al. achieved a remarkable caries inhibition (40%) by using 7 J/cm² of threshold.12 Liu et al.20 also reported a significant protection of enamel demineralization after Er:YAG laser irradiation using puls energies of 100 and 200 mJ. Therefore, Er:YAG laser irradiation at 100 mJ was used in this study.

The results of our in vitro study have shown that, among the irradiated groups, the samples submitted to laser irradiation in combination with or without APF gel application did not differ from each other with respect to the mean lesion depth. However, mean lesion depth of the group, in which APF gel treatment used after the laser application was lower than the group of the laser treatment alone. Furthermore, mean lesion depth of APF gel treatment combined with the laser application was statistically significantly reduced compared to the APF gel treatment alone. These results are promising for the future researches to investigate the effectiveness of laser treatment for the prevention of the dental hard tissues.

The microscopic appearances of the representative caries-like enamel lesions from each group were also given in Figures 1-4. These appearances can be correlated with the mean lesion depth findings among the four treatment groups.

The increase in the enamel's acid resistance after laser irradiation is attributed to the photothermal effects, instead of photomechanical effects, as seen for the ablation process.10 Fowler and Kuroda17 described the necessity of a temperature ranging from 100°C to 650°C to promote those photothermal effects for increasing the enamel acid resistance. However, questions arise as to whether these temperature increases can affect the surrounding tissues and possibly cause pulp damage. Therefore, water cooling was used during the laser irradiation in this study.

The present study is limited to use just one type of laser with only one sub-ablative parameter of 100 mJ. Therefore, there is a need for further researches considering the above mentioned limitations to determine whether Er:YAG laser at
Table 1. Mean lesion depths of the groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>Mean (μm)</th>
<th>Std. Deviation</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 *</td>
<td>20</td>
<td>134.844</td>
<td>32.552</td>
<td>118.98</td>
<td>99.15</td>
<td>218.13</td>
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<tr>
<td>G2 t, q</td>
<td>20</td>
<td>90.226</td>
<td>18.729</td>
<td>109.07</td>
<td>39.66</td>
<td>118.98</td>
</tr>
<tr>
<td>G3 t</td>
<td>20</td>
<td>109.065</td>
<td>25.329</td>
<td>99.15</td>
<td>79.32</td>
<td>178.47</td>
</tr>
<tr>
<td>G4 q</td>
<td>20</td>
<td>74.362</td>
<td>23.085</td>
<td>79.32</td>
<td>19.83</td>
<td>99.15</td>
</tr>
</tbody>
</table>

Superscript letters show statistically homogeneous subgroups (α=0.05)

Figure 1. No-treatment representative lesion (polarized light microscope, magnification x100).

Figure 3. Acidulated phosphate fluoride (APF) gel application alone representative lesion (polarized light microscope, magnification x100).

Figure 2. Er:YAG laser irradiation alone representative lesion (polarized light microscope, magnification x100).

Figure 4. Er:YAG laser irradiation before APF gel application representative lesion (polarized light microscope, magnification x100).

Sub-ablative conditions can reduce the enamel solubility to acids and increase the fluoride incorporation on enamel.

ACKNOWLEDGMENTS

The authors would like to thank Mr. Timur Ertekin (DDS) for his kind support when using the laser device.

This study was presented at the meeting of the 86th General Session & Exhibition of the International Association for Dental Research (IADR).
REFERENCES


