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Optimal Er:YAG laser energy for preventing enamel demineralization

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Summary *Objectives*: The purpose of this study was to identify the optimal laser energy range of Er:YAG laser irradiation for laser-induced caries prevention (LICP).

Methods: Twenty-one human non-carious molars were selected. The teeth were covered with nail varnish, except two 4 mm×1 mm windows on both the buccal and lingual surfaces. The windows were randomly assigned to groups A, B, C and D, receiving no irradiation, 100, 200 and 300 mJ irradiation, respectively. The pulse width 10 pps (pulse per second) with a 1.0 mm spot size was used. After the laser treatment, each tooth was cut into two halves longitudinally. Then 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. Lesion depth was measured using polarized light microscope coupled with an image analysis software. One-way ANOVA and *post-hoc* Tukey tests were used for evaluation of treatment effects.

Results: The laser treatments of 100 and 200 mJ have demonstrated significant protection of enamel demineralization ($p=0.01$ and 0.001, respectively), but not the treatment with 300 mJ ($p=0.106$). A smaller lesion depth was observed for the 200 mJ group (97.1 μm) than that of the 100 mJ group (105.6 μm). Compared with the control, a lesion reduction of 32.78 and 26.93% for the 200 mJ group and the 100 mJ group were obtained, respectively.

Conclusion: Caries prevention may be achieved by using Er:YAG laser treatment if the optimal range of laser parameters for LICP can be employed.

Introduction

The Erbium-doped:Yttrium-aluminum-garnet (Er:YAG) laser, which emits at a wavelength of 2.94 μm in the mid-infrared region, has a potential for hard-tissue treatment due to its high

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absorbability in water and hydroxyapatite.[1,2] It is the first dental laser approved to be used for hard tissue ablation by the U.S. Food and Drug Administration (FDA) in 1997, and has also demonstrated significant effects on caries prevention.[3,4] However, the optimal energy range for caries prevention by using Er:YAG laser has not yet been reported.

When enamel was heated, the acid resistance increased from 100 to 200 °C but then decreased between 300 and 400 °C.[5] If the photothermal effect is essential for laser-induced caries prevention (LICP), it is possible that LICP may decrease when the laser energy is beyond the optimal range. On the other hand, if the laser energy is below the optimal range, the LICP may not be significant.[6]

Therefore, the purpose of this study was to identify the optimal range of Er:YAG laser energy for LICP.

Materials and methods

Tooth selection and grouping

Twenty-one human non-carious molars, stored in 0.1% thymol solution, were selected and cleaned. The teeth were covered with nail varnish, leaving two 4 mm × 1 mm windows on both the buccal and lingual surfaces at the middle third of the crown. The windows were randomly assigned to groups A, B, C and D.

Laser treatment

An Er:YAG laser (Opus 20, Sharplan 4020M, Israel) emitting at a wavelength of 2.94 μm was used in this study. Based on the results of pilot studies, group A was kept as the control group, and teeth of groups B, C, D were treated with the laser energies of 100, 200 and 300 mJ, respectively. Without water spray, the operation was performed by clamping the handpiece of the laser and moving the teeth manually with 10 pps (pulse per second), and 1.0 mm spot size. Since the size of window is 1 mm by 4 mm and the focal spot of the laser is 1.0 mm in diameter, the irradiation was carried out in a series of four steps of one-second irradiation each. This procedure was repeated three more times so that each 'spot' in a window is irradiated four times. Clinically, 600–700 mJ has been used to remove caries and for cavity preparation. Based on our pilot studies, the irradiation energy of 100, 200 and 300 mJ were chosen because these sub-ablative parameters are much lower than that for cavity preparation, and is very unlikely to damage the normal tooth structures. If we would use water spray, a higher energy may be needed for significant LICP and thus increase the possibility of harming the peripheral dental tissues. The energy densities were calculated to be 12.7, 25.5 and 38.2 J/cm^2 for the B, C and D groups, respectively.

pH-cycling process

After the laser treatment, each tooth was cut into two halves longitudinally (disto-mesial) by an alloy grinder (DEMCO™, Dental Maintenance Co., Inc. Bonsall, CA, USA). The cut surfaces were covered with nail varnish and dried for 24 hours. A two-day pH-cycling scheme was performed, with an 18-hour demineralization followed by a 6-hour remineralization, with a stirring speed of 130 rpm at 37 °C.[7] 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 de-ionized 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. All tooth halves were stored in plastic containers with 100% humidity before being sectioned.

Evaluation of demineralization

A Silverstone-Taylor™ hard tissue microtome (series 1000 Deluxe, SciFab, Littleton, Co, USA) was used to obtain several sections of 120 ± 20 μm in thickness from each window. Samples were characterized with stereomicroscope. Five teeth damaged during the procedures were discarded.

With water as the imbibition solution, the demineralization patterns of selected slices were assessed using a polarized light microscope (Olympus™ BH-2, Olympus Corp. of America, New Hyde Park, NY, USA). Using the Micro Image (Olympus™, Japan), a representative lesion area (200 μm in width) of each section was selected and measured as shown in Fig. 1. The "Lesion Area" value was divided by 200 μm to produce the average lesion depth for each section. The measurements of 4 ± 2 sections from each window were averaged to represent the window lesion.

Statistical analysis

The lesion depth (μm) obtained with the above method was used as the dependent variable. The independent variable was the laser energy of four levels, including 0, 100, 200 and 300 mJ.