Nd:YAG Laser in Caries Prevention: A Clinical Trial

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Background and Objective: It is widely known that Nd:YAG can increase enamel resistance to demineralization; however, there are no studies that report the application of Nd:YAG associated with topical application of fluoride in vivo. The aim of this study was to evaluate the effects of the Nd:YAG laser, when associated with the topical application of acidulated phosphate fluoride (APF), for preventing enamel demineralization in vivo.

Materials and Methods: A double-blind crossover experimental design was used, in which 121 teeth of 33 volunteers were selected. In all volunteers, the right side teeth were selected for Nd:YAG laser + APF application (lased group) and the left side teeth were kept as control group (only APF application). Nd:YAG laser was applied at 60 mJ/pulse, at a repetition rate of 10 Hz and fluence of 1,300 cm⁻² (absorption coefficient is typically between 0.5 and 1.4 m), hemoglobin and other pigments, such as melanin are strong absorbers of Nd:YAG laser, when associated with other pigments, such as melanin are strong absorbers of Nd:YAG laser, when associated with topical application of acidulated phosphate fluoride (APF), for preventing enamel demineralization in vivo.

Results: After 1 year, this in vivo experiment showed a reduction of 39.2% in caries incidence in lased group when compared with the control. The number of white-spots or caries cavities decreased significantly (P = 0.0043) in the Nd:YAG laser group; the formation of white-spots was significantly less (P = 0.0031) when compared with the number of lesions in the control group.


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Key words: dental enamel; enamel demineralization; fluoride; in vivo study

INTRODUCTION

Although a declining incidence of dental caries worldwide in the last decades has been reported, it is still the most prevalent disease in childhood and adolescence [1,2]. Due to the widespread use of fluoride, lasers (combined with fluoride) have been tested on teeth to improve dental enamel properties in order to enhance resistance to demineralization.

Since the 1960s, many studies have reported the effect of laser irradiation on dental enamel for the prevention of dental caries. These studies used different types of lasers: ruby [3], neodymium [4,5], CO₂ [6], argon [7], and erbium [8] lasers. Neodymium, CO₂, and erbium lasers have been developed for caries inhibition treatments by localized surface heating [6]. To prevent dental caries, the laser irradiation has to modify the composition of dental substrate, promoting an increase in resistance to demineralization [9]. Furthermore, laser energy must be strongly absorbed and efficiently converted to heat without damage to underlying or surrounding tissues.

Among the lasers indicated in caries prevention, the Nd:YAG laser is one of the most studied. In the visible and near infrared wavelengths (λ<1.4 μm), hemoglobin and other pigments, such as melanin are strong absorbers of Nd:YAG laser, when associated with other pigments, such as melanin are strong absorbers of Nd:YAG laser, when associated with topical application of acidulated phosphate fluoride (APF) gels increases the concentration of fluoride products on enamel [15]. Calcium fluoride is the material responsible for the cariostatic potential of topically used fluoridated products, and the acidic pH of acidulated phosphate fluoride (APF) gels increases the concentration of fluoride products on enamel [16]. However, after topical application, the concentration of calcium fluoride, which acts as a reservoir releasing fluoride on enamel, decreases after a short period of time [17].

Recently, it was found that laser irradiation, combined with topical fluoride treatment, can induce an even greater increase in caries resistance, and there are several mechanisms to explain the improvement of caries resistance following laser and fluoride application on enamel. Some studies reported that laser irradiated enamel can...
MATERIALS AND METHODS

After approval by the Committee on Human Research at the School of Dentistry, University of São Paulo, and at the Nuclear and Energy Research Institute, IPEN–CNEN/SP, 63 premolars and 58 mandibular molars teeth were selected randomly from 33 volunteer children and adolescents aged from 7 to 15 years old. All patients were recruited from the Graduate Program clinic of the School of Dentistry of University of São Paulo, and teeth were evaluated and selected by three calibrated observers, using the following selection criteria: age between 7 and 15 years; teeth without enamel defects, morphological anomalies, decalcifications, signals of fluorosis, white-spots and caries; teeth without enamel defects, morphological anomalies, decalcifications, signals of fluorosis, white-spots and caries; teeth that were not previously bonded. The homologous of all irradiated teeth was in identical condition. For clinical evaluation, all teeth were brushed with pumice paste and submitted to radiographic exams. Vitality tests were performed with cold and heat in all teeth selected for this research.

Informed consent was obtained, and after this, 121 teeth received only topical application of fluoride and 121 teeth received the association of laser with fluoride treatment \( n_{\text{total}} = 242 \). In all volunteers, the right side teeth were selected for Nd:YAG laser application (lased group) and the left side teeth were kept as control group. In the lased group, occlusal surfaces were covered with a thin layer (~100 μm) of a photosensitizer composed of triturated coal (particles of ±10 μm diameter) diluted in equal parts of deionized water and 99% ethanol [26]. This mix formed a paste with fluid consistency that allowed it to be applied with a #01 brush.

The Nd:YAG laser (Pulse Master 1000 ADT - USA) used in this work emits pulses at 1.064 μm, with a 300 μm quartz fiber optic delivery system operating in contact mode (spot size of 300 μm), temporal width of 100 microseconds and operates at 10–100 repetition rates. Nd:YAG laser was used to irradiate all occlusal surfaces, scanning them under the conditions of 0.6 W, 60 mJ per pulse, 10 Hz repetition rate and fluency of 84.9 J/cm². The procedure of dye application followed by laser irradiation was repeated three times in order to assure enamel melting. After this procedure, the teeth were brushed with pumice paste and a fluoride gel (1.23% F⁻, Nupro® Dentply, York, PA) was applied to both lased and control groups for 4 minutes.

In this study, a double-blind crossover experimental design was used. The clinical evaluation of the volunteers was performed 12 months after laser irradiation by another calibrated observer. The teeth were checked for dental caries by visual observation, dental explorer inspection, vitality tests, and radiographic examinations. The presence of white-spots and caries cavities in both molar and premolar teeth was considered.

Comparisons were made among the groups using the Q-square test, considering alpha level <0.05.

RESULTS

The clinical evaluation performed after 12 months showed 13 teeth with caries cavities or white-spots (11 molars and 2 premolars) in the lased group. In this group, there were 4 caries cavities and 9 active white-spots. However, in the control group, 33 teeth with caries cavities or white-spots (24 molars and 9 premolars), divided into 8 caries cavities and 25 active white-spots were detected. In the statistical analysis, the descriptive level of 0.0011 between the treatments was found, and it was possible to conclude that the rate of reduction in dental caries was 39.2% in lased group. The results of the statistical analysis are shown in Table 1.

The number of white-spots or caries cavities decreased significantly \( (P = 0.0043) \) for combined fluoride and Nd:YAG laser group when compared with control group (Fig. 1). However, this difference was observed when the white-spot lesions in lased group (9 lesions), which was significantly less \( (P = 0.0031) \), was compared with the number of lesions in control group (25 lesions). However, for caries cavities, no statistical difference \( (P = 0.2362) \) between the lased and control groups was found.

Considering the evaluated teeth, it was possible to conclude that there was a higher prevalence of caries in molars \( (P = 0.0051) \). In the molar teeth only \( (n = 116) \), a 1% significance \( (P = 0.0085) \) between lased (11 teeth with caries or white-spots) and control groups (24 teeth with caries or white-spots) was observed. In the lased group, four molar teeth presented carious cavity and in the control group there were eight molar teeth with carious cavity. All caries lesions were found on the occlusal surfaces. When premolar teeth were compared \( (n = 126) \), a 1% statistical difference \( (P = 0.0272) \) between lased (nine teeth with active white-spots) and control groups (two teeth with
active white-spots) was observed. No carious cavities were observed in the premolar teeth. Moreover, reductions of 45.9% caries in molars and 22.4% in premolars were seen when laser was associated with fluoride. Figure 2 illustrates the incidence of caries lesions in lased and control groups.

**DISCUSSION**

Previous studies have been carried out to verify the potential of using Nd:YAG laser in caries prevention [3,4,10,21,27]. Most studies used *in vitro* methodologies and reported promising results. Since 1960, it has been demonstrated that lasers can significantly alter the permeability, the crystallinity, and acid-solubility of enamel, promoting an increase in its resistance to demineralization [3,4,10]. Indeed, due to the surface temperatures achieved during a high-intensity laser irradiation on enamel, loss of water and carbonate can occur at temperatures between 100 and 1,100 °C; at temperatures between 100 and 650 °C, the oxidation of phosphates and formation of pyrophosphates can be found, and at temperatures up to 1,100 °C the formation of new crystalline phases such as tricalcium phosphate (α-TCP and β-TCP phases) can be promoted. Previous studies reported surface melting and temperatures up to 600 °C when enamel was irradiated with Nd:YAG at the same parameters of the present study [26], which confirms the potential of this wavelength for caries prevention.

Several *in vitro* studies have demonstrated an increase in resistance to demineralization of enamel irradiated with Nd:YAG laser, proving its potential in preventing caries. At the fluence of more than 30 J/cm², a 90% inhibition of calcium dissolution was reported [3]. Furthermore, at a pulse energy of 0.75 J, a significant inhibition of calcium dissolution was documented [27], and when combined with fluoride varnish, Nd:YAG inhibited 43% of lesions in pits and fissures and 80% of lesions on smooth surfaces in comparison with the non-treated groups [21].

Even with remarkable *in vitro* studies, there are few *in vivo* studies that investigate Nd:YAG laser for caries prevention. In a previous clinical study, the progression of white-spot lesions was controlled in orthodontic patients who received laser treatment combined with APF solution [28]. Recently Nd:YAG laser was used in the treatment of early childhood caries. Good patient compliance and advantages in fluoride penetration into the tooth were reported [29].

Some *in vivo* studies support the use of Nd:YAG laser for caries prevention at 60 mJ per pulse. White and Goodis (1993) [30] stated that pulsed Nd:YAG laser should not exceed 1 W and 10 Hz in animal studies [31,32], and Goodis et al. (1992) [33,34] also showed no histological evidence of pulp reaction after 1 month, when Nd:YAG was applied at 150 mJ/pulse for 2 minutes on human molars. After that, White et al. (1993) [35], in a clinical evaluation of 3 years, showed no evidence of any symptoms or pulp necrosis in

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**TABLE 1. Comparisons of Prevalence Between the Treatments and Descriptive Levels of Statistical Analysis (Q-Square Test)**

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>General Caries cavities</th>
<th>White-spots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between treatments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molars</td>
<td>0.0311</td>
<td>0.2227</td>
</tr>
<tr>
<td>Premolars</td>
<td>0.0131</td>
<td>0.0131</td>
</tr>
<tr>
<td>Between analyzed teeth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lased group</td>
<td>0.0109</td>
<td>0.0499</td>
</tr>
<tr>
<td>Control group</td>
<td>0.0005</td>
<td>0.6547</td>
</tr>
</tbody>
</table>

The dark columns represent statistically significant differences.
patients who had received Nd:YAG irradiation at 100 mJ/pulse for caries removal. Our study used less energy per pulse (60 mJ/pulse) than the above-mentioned study, and the same beam diameter and repetition rate, therefore it is possible to consider that the use of Nd:YAG for preventive purposes under the conditions chosen in the present study is safe for pulp vitality. Moreover, a previous in vitro work [26], using the same parameters as those used in the present study, reported that Nd:YAG laser did not promote harmful temperature increases in pulp.

In the present clinical trial, the application of APF combined with Nd:YAG laser confirmed the increase in resistance in enamel demineralization already reported. Within the present study, Nd:YAG laser irradiation provided a reduction of slightly more than 39% in caries incidence compared with the non-treatment control. These findings are in agreement with those reported for the effect of combined fluoride and Nd:YAG laser irradiation treatment on in vitro enamel caries (reduction of 40% for premolars caries) [21,27]. Previous in vivo studies reported a reduction of 62% in lesion depth when combined fluoride and argon laser were applied to premolars surfaces [7].

A significant synergism has been shown between laser and fluoride in the reduction of enamel solubility. Indeed, topical APF application promotes the dissolution of more soluble apatite crystals, and a large quantity of CaF$_2$ is formed on the surface [16,36]. Laser irradiation can retain fluoride ions longer than unlased enamel, and the mechanisms of this fluoride retention are still unknown [37]. It was proposed that laser irradiation can promote the formation of microspaces in enamel, which would facilitate the fluoride incorporation [38]; moreover, laser irradiation can induce the formation of fluorapatite by incorporation of fluoride into the melted layers of the enamel surface [20]. Another suggested mechanism is that laser irradiation can increase fluoride diffusion through enamel and generate fluoride reservoirs [18].

In the present study, the combination of topical fluoride treatment following laser irradiation provided an even greater degree of caries resistance. Since heat was found to enhance the uptake of fluoride, it was speculated that the thermal effect of the laser was the main factor in promoting fluoride uptake and an increase in enamel resistance to demineralization [39].

Even though the study patients were seen again 1 year after treatment, it was not possible to determine the durability of the effects of laser on fluoride uptake. Further researches with extensive follow-up are still necessary to provide information about the long-term effects of Nd:YAG laser in caries prevention.

CONCLUSION

From the results of this study, it can be concluded that, at the parameters used, Nd:YAG laser irradiation followed by topical fluoride application might be an effective mode of treatment in the clinical prevention of pit and fissure caries in permanent teeth.

ACKNOWLEDGMENTS

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REFERENCES


22. ZEPELL ET AL.


