

# Nd:YAG Laser Irradiation Effect on Apical Intracanal Dentin - A Microleakage and SEM Evaluation

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The purpose of this *in vitro* study was to evaluate the effect of neodymium:yttrium-aluminum-garnet (Nd:YAG) laser irradiation on intracanal dentin surface by SEM analysis and its interference in the apical seal of filled canals. After endodontic treatment procedures, 34 maxillary human incisors were randomly assigned to 2 groups. In the negative control group (n=17), no additional treatment was performed and teeth were filled with vertically condensed gutta-percha; in the laser-treated group (n=17), the root canals were irradiated with Nd:YAG laser (1.5 W, 100 mJ, 15 Hz) before filling as described for the control group. Two specimens of each group were prepared for SEM analysis to evaluate the presence and extent of morphological changes and removal of debris; the other specimens were immersed in 0.5% methylene blue dye (pH 7.2) for 24 h for evaluation of the linear dye leakage at the apical third. SEM analysis of the laser-treated group showed dentin fusion and resolidification without smear layer or debris. The Student's *t*-test showed that the laser-treated group had significantly less leakage in apical third than the control group. Within the limitations of this study, it may be concluded that the morphological changes on the apical intraradicular dentin surface caused by Nd:YAG laser resulted in less linear dye apical leakage.

Key Words: Endodontics, laser, apical leakage, intracanal irradiation.

## INTRODUCTION

The fundamental part in endodontic therapy is the removal of inorganic and organic debris followed by the appropriate filling of the canal space in order to seal it off from the surrounding oral tissues. The main purpose of this last step is to achieve a complete seal that prevents bacterial leakage and a further recontamination of root canal dentin in the entire root canal system, particularly in the apical third. Apical leakage has been proven an important reason for root canal treatment failure and its occurrence is generally associated with deficient smear layer removal (1-3).

A number of studies have demonstrated that the

traditional method for root canal preparation produces a significant amount of smear layer that can adhere on the dentinal walls, obliterating the dentinal tubules. It thus reduces dentinal permeability and hinders penetration of intracanal drugs into dentin, even when chemical irrigation is used combined with mechanical instrumentation. It has been claimed that the incidence of leakage is significantly reduced in the absence of smear layer and that smear layer removal is capable of enhancing seal ability and hence increasing resistance to bacterial penetration (4).

New techniques that may result in higher success rates have recently been developed and the use of lasers in Endodontics has appeared as an interesting adjunct to

root canal treatment, especially the neodymium-doped yttrium aluminium garnet laser (Nd:YAG). Nd:YAG laser can be absorbed by mineral structures, like phosphates and carbonate hydroxyapatite, and disrupts crystal structures by thermochemical action. The morphological changes are characterized by melting and resolidification processes on dentin surface, which can improve sealing ability and reduce dentinal permeability (5).

It has been verified that the use of Nd:YAG laser in combination with hand filing could produce clean root canals without smear layer and tissue remnants (6,7). Nd:YAG laser was capable of sealing the root canal wall dentin by deposition of glass-like materials and significantly reduced dentin permeability. More recently, it was also reported that high-level lasers were capable of improving apical seal, thus preventing microorganisms to invade the periradicular tissues (8-12).

The purpose of this study was to evaluate the effect of Nd:YAG laser irradiation on the intracanal dentin surface by SEM analysis and its interference in the apical leakage of filled root canals.

## MATERIAL AND METHODS

This study was conducted after approval by the Ethics Committee of FOU SP - University of São Paulo (Protocol #92/2008). Thirty-four human maxillary incisors were obtained from the University's Tooth Bank and radiographs were taken to verify the presence of any anomaly in the pulp chamber or root canal. The teeth had their crowns sectioned at the cemento-enamel junction and root canal preparation was carried out using K-files and Endo-PTC lubricant (Fórmula e Ação, São Paulo, SP, Brazil) combined with 2.5% NaOCl. The working length of each root canal was then established 1.0 mm short of the apical foramen and apical preparation was made with a #55 file. A final flush was done using 15 mL of 17% EDTA (Fórmula e Ação).

After instrumentation, teeth were randomly assigned into 2 groups: a negative control group (n=17), which received no treatment before root filling; and a laser-treated group (n=17), which was irradiated with Nd:YAG laser before root filling. Two specimens of each group were prepared for SEM analysis and the other 15 were prepared for dye penetration test.

### Specimen Treatment

Root canals of the control group were filled with

gutta-percha and AH Plus sealer (Dentsply, DeTrey, GmbH, Konstanz, Germany) using lateral condensation technique immediately after instrumentation. The endodontic sealer was mixed according to the manufacturer's instructions and placed into the canal with a master gutta-percha cone. The master cone was fitted to the working length and lateral condensation was then carried out using accessory gutta-percha cones. The excess of gutta-percha was removed with a heated plugger and the remaining filling material was vertically condensed with a cold plugger.

In the laser-treated group, the root canal walls were irradiated with a Nd:YAG laser (Pulse Master 1000 IQ; American Dental Technologies, Southfield, MI, USA), with a wavelength of 1,064 nm, at the following parameters: pulse duration 100  $\mu$ s; energy *per* pulse 100 mJ; frequency 15 Hz and output power 1.5 W. The beam was delivered through a 320- $\mu$ m optical fiber.

Irradiation was executed by introducing the fiber-optic cable along the entire length of the root canal, irradiating all the dentinal walls from apical to cervical region, with helicoidal movements at a speed of 1 mm/s. This procedure was repeated 4 times. The specimens were kept at room temperature for 20 s between each irradiation to prevent the temperature rise from exceeding the accepted allowance. After laser irradiation, root canals were filled as described for the control group.

### SEM Analysis

Two roots of each group were prepared to SEM analysis, in order to verify the apical surface morphology with and without Nd:YAG laser irradiation. The teeth were split in the buccolingual direction and the sections were dehydrated by a series of graded ethanol solutions, sputter-coated with gold and then examined with a scanning electron microscope (XL30; Philips, Eindhoven, Netherlands). The dentin surface located 3 mm short of the apex and equidistant from lateral walls was analyzed for the presence and extension of morphological changes and removal of debris.

### Dye Penetration

The remaining specimens were externally coated with 2 layers of nail polish, except for apical 2 mm and were immersed in 0.5% aqueous solution (pH=7.2) of methylene blue (Fórmula e Ação) for 72 h at 37°C and

100% of humidity. Thereafter, they were thoroughly rinsed in running water and embedded individually in stone cast blocks, which were then cut longitudinally.

For analysis of dye penetration, images each root half were taken with a digital camera attached to a stereomicroscope (SMZ/2B; Nikon, Tokyo, Japan) under the same magnification. Linear dye penetration was measured by a single operator, blinded regarding groups, using Image J 1.41 software (Wayne Rasband; National Institutes of Health, Bethesda, MD, USA).

Data were subjected to statistical analysis using Kolmogorov-Smirnov test for normality and then the Student's t-test for independent variables was used at a significance level of 5%.

## RESULTS

Student's t-test showed that the laser-treated group presented significantly less linear dye leakage ( $1.0 \pm 0.41$  mm) than control group ( $1.68 \pm 0.45$  mm) ( $p=0.0002$ ).

SEM analysis of control group showed the surface free of smear layer and open dentinal tubules (Fig. 1A). In the laser-treated group, it was observed an irregular and non-uniform surface with dentin fusion and resolidification without smear layer and debris (Fig. 1B). Areas with some dentinal tubules overlapping the fused dentin areas could also be observed.

## DISCUSSION

Proper seal of the apical region is an important

issue in preventing leakage and possible reinfection of root canal system. In this way, the importance of smear layer elimination to improve the success rate of filled teeth has already been established (1,2).

Several laser systems have been investigated in Dentistry over almost 30 years and Nd:YAG laser is well established for endodontic purposes. Due to laser wavelength and to the flexible conductors, Nd:YAG laser can be used to stop bleeding after pulpectomy or apicoectomy, to improve disinfection of root canals (13,14), and to remove smear layer and seal dentinal tubules, thus reducing dentinal permeability (8,15).

In the present study, the laser-treated showed the lower values of dye penetration than the control group. The smear layer was probably fused and resolidified together with root canal dentin after treatment with Nd:YAG laser, acting as a single substrate. This outcome is in agreement with results found in other studies that investigated the occurrence of melting and recrystallization of smear layer using this type of laser (5). The influence of Nd:YAG laser on apical seal when used before root canal filling with different resin-based cements has also been studied. It has been found that Nd:YAG was able to reduced the marginal permeability, regardless of the type of root canal filling material used (12).

Goya et al. (8) demonstrated by SEM that Nd:YAG laser irradiation combined with black ink increases the removal of smear layer and reduces apical leakage following filling significantly. After the laser treatment, the smear layer was melted or had evaporated and leakage was observed in 20% of the specimens.

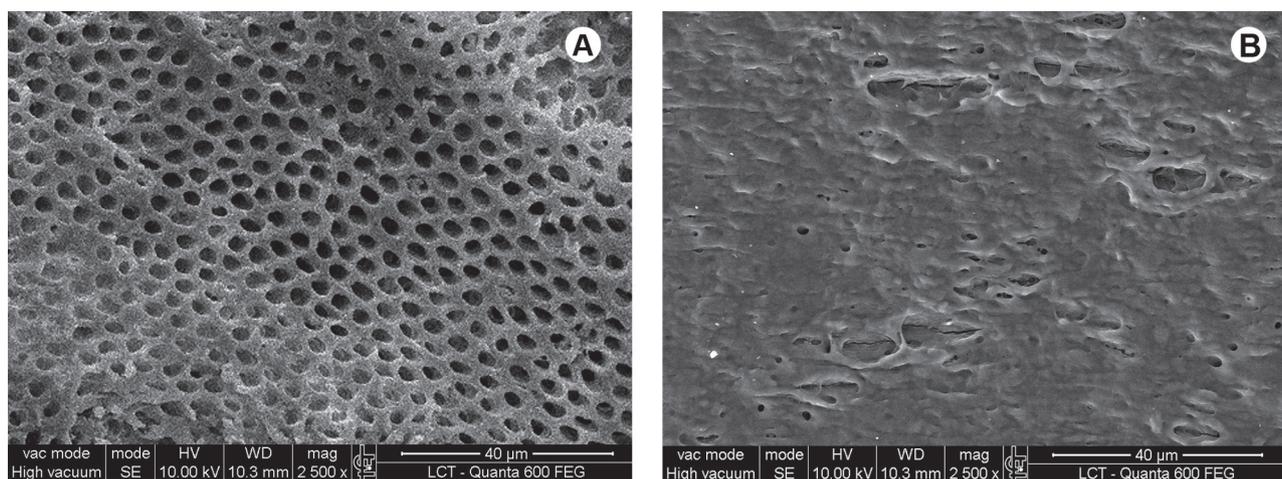


Figure 1. SEM micrographs. A = control group (CG). Dentinal surface free of smear layer and with open dentinal tubules; B = experimental group (LG): Dentin fusion and resolidification after laser irradiation with no smear layer or debris.

However, when black ink was used before irradiation, no leakage occurred. Black ink can be used in association with Nd:YAG laser irradiation because its capable of absorbing the laser beam in a higher proportion (16,17) and may enhance the laser effects. In the present study, even though no dye was used, SEM analysis also revealed melted surfaces with recrystallized areas in the laser-treated group.

Park et al. (10) investigated the effect of Nd:YAG laser irradiation on apical leakage of filled root canals using an electrochemical method. The electrical resistance between standard and experimental electrodes in the canals was measured over a period of 10 days. This method could provide quantitative measurements of apical leakage and the opportunity to study leakage over a continuous time period. Although irradiated specimens showed less leaked than the control specimens, as found in our study, increasing apical leakage over time was observed in all groups. This results suggests that laser can prevent apical leakage in a certain degree although it is difficult to complete inhibit its occurrence.

Various methods have been used to evaluate apical seal after different root canal preparation techniques. Because of its sensitivity and simplicity of use, dye penetration is commonly used as an indicator of apical infiltration. The depth of dye penetration represents the space between the root filling and the canal walls. The assessment of linear dye penetration apically or coronally is the most common laboratory method for investigating the accommodation of a root filling to the canal walls (18). As studies that use score systems are very subjective, in this study methylene blue infiltration was linearly measured to quantify apical leakage. Like any other method, dye and tracing tests do not represent or simulate the exact behavior of these surface treatments on clinical conditions (18). The measurement of linear dye penetration analyses only one interface between dentin surface and filling material. However, since there is no single universally accepted model of leakage testing in Endodontics, this leakage test can be used to compare the effect of laser intracanal irradiation.

The less leakage observed in the laser-treated group in the present study may be due to the significant removal of the smear layer by Nd:YAG laser. It has been reported that the removal of smear layer by lasers such as Er:YAG and Er,Cr:YSGG is greater than that promoted by Nd:YAG laser (19,20). Already established as a device for hard tissue preparation, these wavelengths are highly absorbed by water, which facilitates tissue

removal through thermomechanical ablation (21,22). Therefore dentinal tubule exposure, increased dentin permeability and smear layer removal are common outcomes associated with them.

The increase of permeability provided by Er:YAG laser could be of interest for permitting a free passage of irrigant solutions through the dentinal tubules, promoting a more effective cleanliness even though this benefit is more associated with chemical-surgical preparation. On the other hand, the decrease in permeability produced by Nd:YAG laser would be interesting at the end of treatment, by promoting almost complete occlusion of dentinal tubules before root canal filling. As different wavelengths cause distinct tissue interactions, the alterations in root canal morphology and permeability promoted by each of them will determine its indication. Nd:YAG laser is capable of sealing dentinal tubules and this mechanism hinders the passage of fluids, promoting less leakage. It was likely the reason for the lowest rate of apical leakage observed in the present study, which corroborates with previous studies (23).

It should be noted that in addition to applications related to the intracanal preparation, the bactericidal effect of high-level lasers is also interesting for the success of endodontic treatment. Nevertheless, among them, only the Nd:YAG laser can achieve a high degree of decontamination, even in deeper dentin layers. In contrast to the radiation at higher wavelengths like those of the Er:YAG and the Er,Cr:YSGG lasers, the radiation of the Nd:YAG laser is poorly absorbed by dental hard substances and therefore deeper penetration in the tissue can be expected (15).

Temperature elevation is an inherent characteristic of high-level lasers and thermal damage is one of the most important issues to be considered in the use of laser for root canal treatment, so deleterious thermal effects to the tissues surrounding the tooth must be avoided. Although temperature increase on root surfaces was not assessed in the present study, it has already been demonstrated that the surrounding periodontal tissues are not damaged if the laser equipment is used within correct parameters and when temperature increment on root surface does not exceeds 10°C above body temperature for more than 1 min (24). Temperature elevation is a function of output intensity and irradiation time. The setting parameters for the present study were based on those safely used for laser application in endodontic treatment for permanent teeth. In addition, to prevent excessive temperature rising during irradiation, the delivery fiber

was constantly moved over the irradiated surface and an interval of 20 s was waited between irradiations (25).

Considering that conventional root canal preparation techniques and endodontic chemical irrigants are insufficient to completely remove infected dentin and pulp tissue, the present results support the use of Nd:YAG laser as an adjuvant of endodontic therapy, as the morphological changes on the apical intraradicular dentin surface caused by Nd:YAG laser resulted in less linear dye apical leakage.

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