

# Effects of Copper Vapor Laser Radiation on the Root Canal Wall of Human Teeth: A Scanning Electron Microscope Study

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## ABSTRACT

**Objective:** The aim of this study is to analyze the effects of copper vapor laser radiation on the radicular wall of human teeth. **Materials and Methods:** Immediately after the crowns of 10 human uniradicular teeth were cut along the cement-enamel junction, a chemical-surgical preparation of the radicular canals was completed. Then the roots were longitudinally sectioned to allow for irradiation of the surfaces of the dentin walls of the root canals. The hemi-roots were separated into two groups: one (control) with five hemi-roots that were not irradiated, and another (experimental) with 15 hemi-roots divided into three subgroups that were submitted to the following exposure times: 0.02, 0.05, and 0.1 s. A copper vapor laser (510.6 nm) with a total average power of 6.5 W in green emission, frequency of 16,000 Hz, and pulse duration of 30 ns was used. **Results:** The results obtained by scanning electron microscope analysis showed the appearance of a cavity in the region of laser beam impact, with melting, recrystallization, and cracking on the edges of the dentin of the cavity due to heat diffusion. **Conclusions:** We determined that the copper vapor laser produces significant morphologic changes in the radicular wall of human teeth when using the parameters in this study. However, further research should be done to establish parameters that are compatible with dental structure in order to eliminate thermal damages.

## INTRODUCTION

RECENT RESEARCH has studied the use of different types of laser irradiation of root canals with the goal of disinfection by thermal effect. In the 1990s, the copper vapor laser (CVL) generated a great deal of interest because it produces high-power (average and peak) coherent radiation in the visible region of the spectrum with a high efficiency of conversion from electric power to radiation compared to other lasers operating in the same spectrum. The CVL operates with a pulsed regime and a repetition band that can vary from the thousands to nearly a hundred thousand pulses per second, depending on the specific system. With very short pulse duration (10–50 ns), this laser has found several applications in procedures that require a short-time duration. The research with this laser has been concentrated in the dermatological field, more specifically selected for use on telangiectasis and patients with port-wine stains.

Penna<sup>1</sup> has researched the use of CVL on enamel and dentin using a power of 7 W and varying exposure times. No morphologic alterations at exposure times of 500 and 600 ms were noted. Only when the exposure times were 800 ms and 1 s on the dentin and 1 s on the enamel were macroscopic morphologic and ultrastructural alterations observed.

In an attempt to minimize damage to the periodontal tissues, Cohen et al.<sup>2</sup> determined that 1 W of power was the maximum Ho:YAG laser energy that could be used in root canals without increasing the temperature of cement by more than 5°C. Gutknecht et al.<sup>3</sup> used the Nd:YAG laser on teeth inoculated with a 10-ml suspension of *Enterococcus faecalis* and obtained results that showed an average bacterial reduction of 99.91% as compared to the nonirradiated group.

Successful laser irradiation depends on the rate of absorption of the specific wavelength and characteristics of density, intensity, and duration of exposure. With these facts in mind,

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and an absence of references in dentistry-related research with this kind of laser, we undertook this study to verify the effects of radiation from a CVL on the dentin walls of root canals and to provide information for future studies.

## MATERIALS AND METHODS

Ten uniradicular human teeth, stored in a 1% sodium hypochlorite solution (Inodon Laboratory, Sao Paulo Brazil), were used in this study. All teeth were x-rayed to confirm the presence of root canals and the absence of complicated anatomy. The crowns were removed from the cement-enamel limit using a steel disc and the entrance to the canals was prepared with a Batt n°4 of 28-mm drill (Maileffer, Ballaigues, Switzerland) in low rotation.

The canals were cleaned with the help of a #10 Kerr instrument (Maileffer) and alternately irrigated with a 1% sodium hypochlorite solution. The anatomical apex of the root was established as the working length.

For final preparation, a series of Kerr instruments (ending with a #40) were used. After each instrument was used, the canal was irrigated with 3 mL of a 1% sodium hypochlorite solution by means of a Luer-type syringe (D-B YALE, Becton Dickinson Surgical Industry, Sao Paulo, Brazil).

### *Preparation of the roots before receiving laser irradiation*

The roots were sectioned longitudinally using a steel disc and cleaved to separate halves, exposing the dentin wall of the root canal for irradiation. The specimens were stored in a glass flask containing a 1% sodium hypochlorite solution.

The roots were divided into two groups: Group I (control)—five hemi-roots that were submitted only to a surgical chemical method of disinfection; and Group II (experimental)—15 hemi-roots that received a surgical-chemical treatment and were then irradiated with a CVL emitting a wavelength of 510.6 nm (green).

The hemi-roots in Group II was aleatory divided into three groups, and the root canals were submitted to irradiation with exposure times of 0.02, 0.05, and 0.1 s, respectively. Two of the teeth were exposed to a one-pulse application and three to ten-pulse applications that were focused at the same locations. Emission wavelength of 510.6 nm (green spectrum), 6.5 W of power with a repetition rate of 16.000 Hz, and irradiation time of 30 ns were used. The energy pulse was set at 0.4 mJ, with a peak power of 13.5 kW. Because the metallic base actuator contained a device that enabled horizontal action with a measurement in millimeters, the irradiation points were spaced a millimeter apart.

The radiation emission was focalized at a distance of 360 mm from the lens, and an electromechanic shutter placed between the lens and the tooth allowed for control of the exposure time. With this system, the minimum diameter of the radiation emission on the tooth was estimated at 10 mm, and the quality of the radiation emission was measured and estimated at  $M^2 = 5$ , with a focal depth of 3.2 mm. Within these parameters, the fluency of the laser at this focal depth was 1.3 J/cm<sup>2</sup>, and the radiation intensity of the pulses was 180 mW/cm<sup>2</sup>.

In all the experiments, the same regime of radiation described above was maintained, varying only the exposure time and the number of pulses on the teeth (Table 1). The time be-

TABLE 1. EXPOSURE TIME AND NUMBER OF LASER APPLICATIONS RELATED TO THE NUMBER OF LASER PULSES AND ACCUMULATED ENERGY

<i>Exposure time (s)</i>	<i>No. of applications</i>	<i>No. of pulses</i>	<i>Laser energy accumulated (mJ)</i>
0.02	1	320	128
0.02	10	3200	1280
0.05	1	800	320
0.05	10	8000	3200
0.1	1	1600	640

tween successive irradiations was always longer than 5 s to guarantee that the temperature at the beginning of each application was uniform and not significantly raised.

### *Preparation for the scanning electron microscope*

After irradiation, the hemi-roots were stored in a sterile glass flask containing a 1% sodium hypochlorite solution. The dehydration process was realized by submitting the teeth to an alcohol treatment that gradually increased in concentration, beginning with a 25°GL solution and increasing to 50°GL, 75°GL (20-min submersion), 90°GL (30-min submersion), and finally in absolute alcohol (60-min submersion). The dehydrated specimens were kept in a sterile dry glass flask until their gold metallization for examination by the scanning electron microscope (SEM).

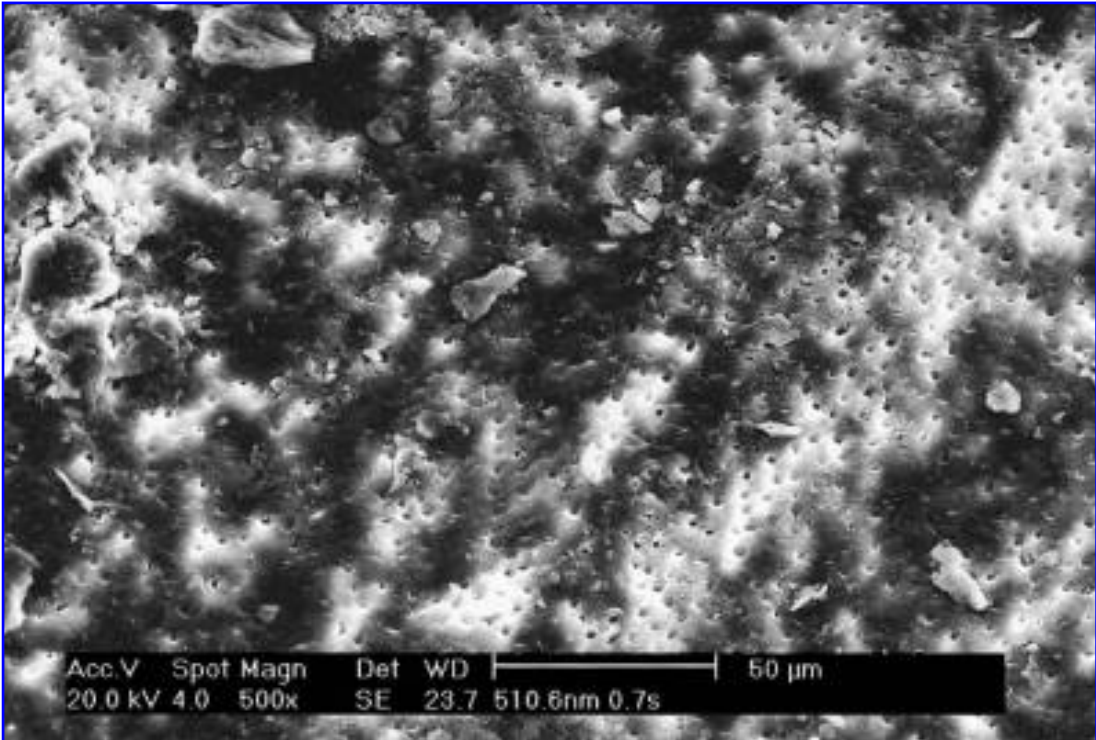
The specimens were analyzed and photographed with a SEM (Philips XL 30, Osaka, Japan). To evaluate the effects of CVL irradiation on the dentin walls of the root canals, magnifications varying from 159–1.279 × were used.

## RESULTS

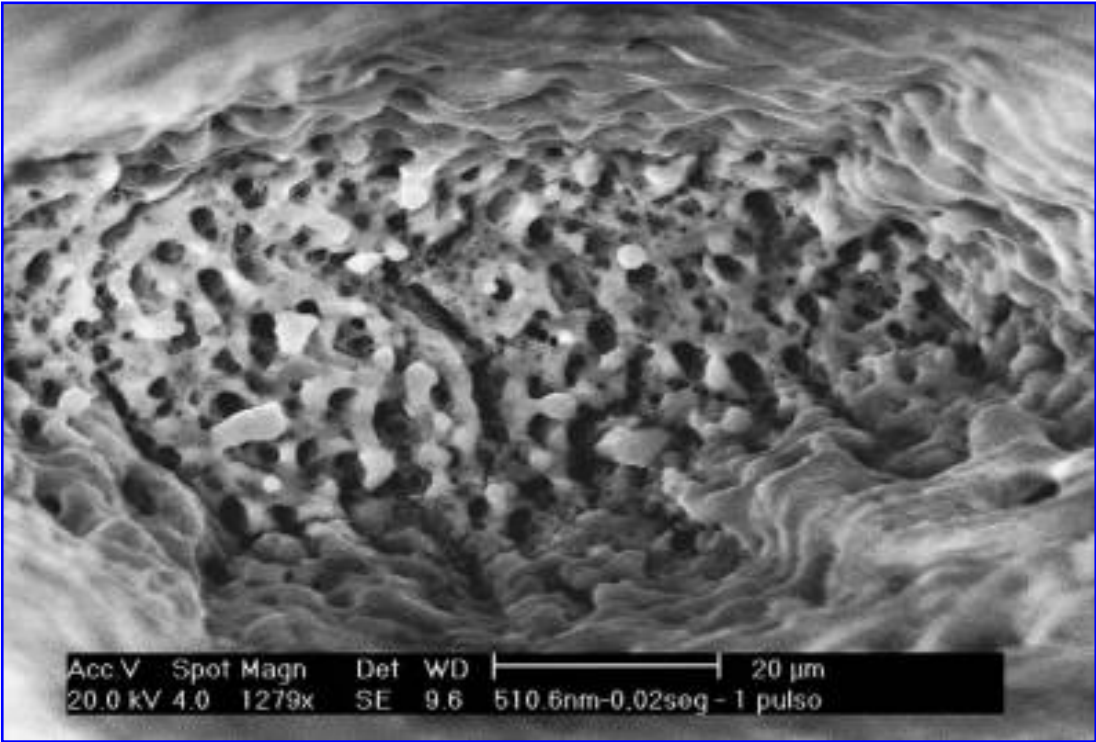
This study demonstrated that, in the control group, the hemi-roots that were chemically and surgically prepared did not show structural or morphologic alteration on the dentinal surfaces. The dentinal tubules were organized, and there was the presence of a smear layer (Fig. 1).

In the experimental group, formation of a cavity on the dentin wall of the radicular canal was observed, with coalition and recrystallization of the dentin around the cavity. The parameters cited above for CVL use remained constant, varying only by exposure time and number of pulses per tooth.

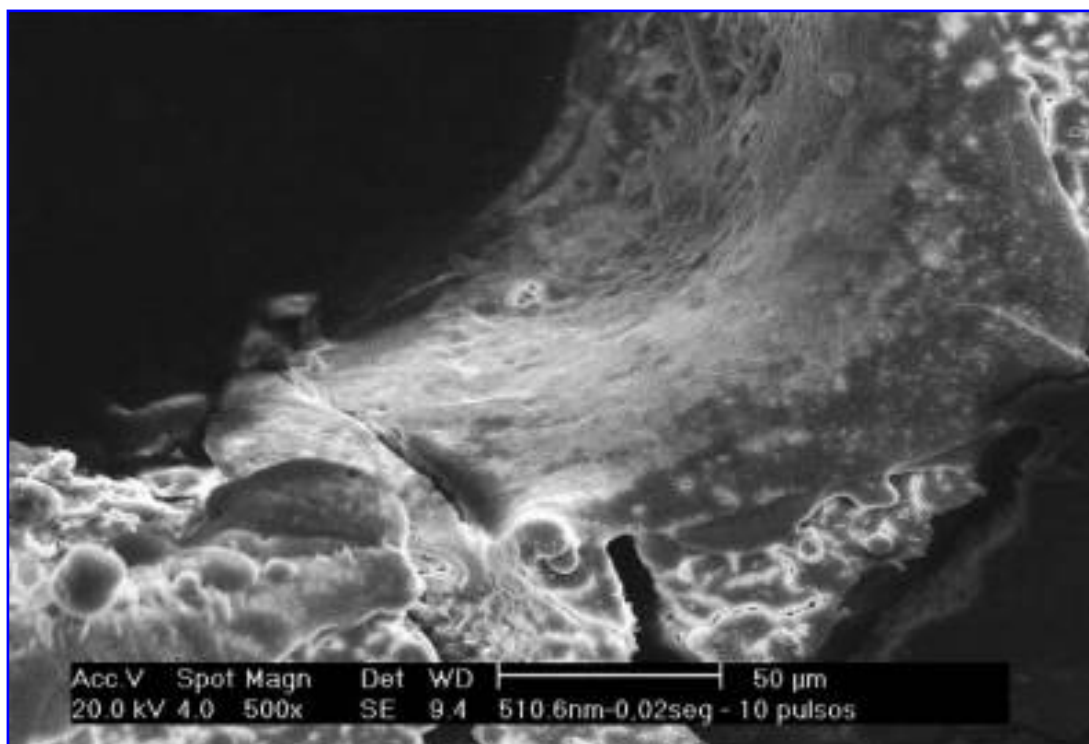
In the irradiated specimens with an exposure time of 0.02 s, there was the formation of a cavity due to dentin evaporation. The walls of the cavity also showed characteristics of melting and recrystallization. The melting resulted from the high temperatures reached by the dentin at the moment of absorption of the CVL radiation, causing the dentinal tubules to close and altering the dentinal surfaces as compared to observations of the control group. When the temperature of the dentin decreased, recrystallization occurred on the irradiated dentinal surfaces (Figs. 2 and 3).



**FIG. 1.** Dentin surface without structural alteration, with organized dentin tubular aperture and the presence of a smear layer (control group). (500 ×)



**FIG. 2.** Formation of cavity due to evaporation, with the walls showing characteristics of coalition and recrystallization (0.02 s/pulse). (11279 ×)



**FIG. 3.** Border of the cavity showing high thermal damage with coalition, recrystallization, and cracking (0.02 s/10 pulses). (500 ×)

The two groups of specimens irradiated for 0.02 s received a single application of 320 pulses and 10 applications of 3,200 pulses, respectively. The diameters of the cavities (the zones thermally affected) that formed were practically the same. However, the edges of the cavities in the specimens that received 10 laser applications showed greater morphologic and ultrastructural alterations.

In the specimens irradiated for 0.05 and 0.1 s, there were cavity formations and the dentin walls of the cavities showed coalition, melting, recrystallization, and cracking. It was also possible to observe the bottoms of the cavities. However, they were deeper as compared to the cavities formed at an exposure time of 0.02 s. It is also important to note that the cavities formed with only one laser application had a smaller diameter and depth than the cavities produced with ten laser applications. The effects that the CVL radiation provoked in the dentin at the edges of the cavities, and in every other extension, were fusion, recrystallization, and crack formation due to heat dissipation (Figs. 4–7).

At an exposure time of 0.1 s, the thermal effects were high, as determined by the size of the cavities that formed, the number of cracks, and the extensive damage. This demonstrated that there was a high morphologic and ultrastructural implication on the dentin.

## DISCUSSION

The utilization of lasers in dentistry is becoming more and more common due to the numerous studies that have been completed with positive results for clinical procedures. After review-

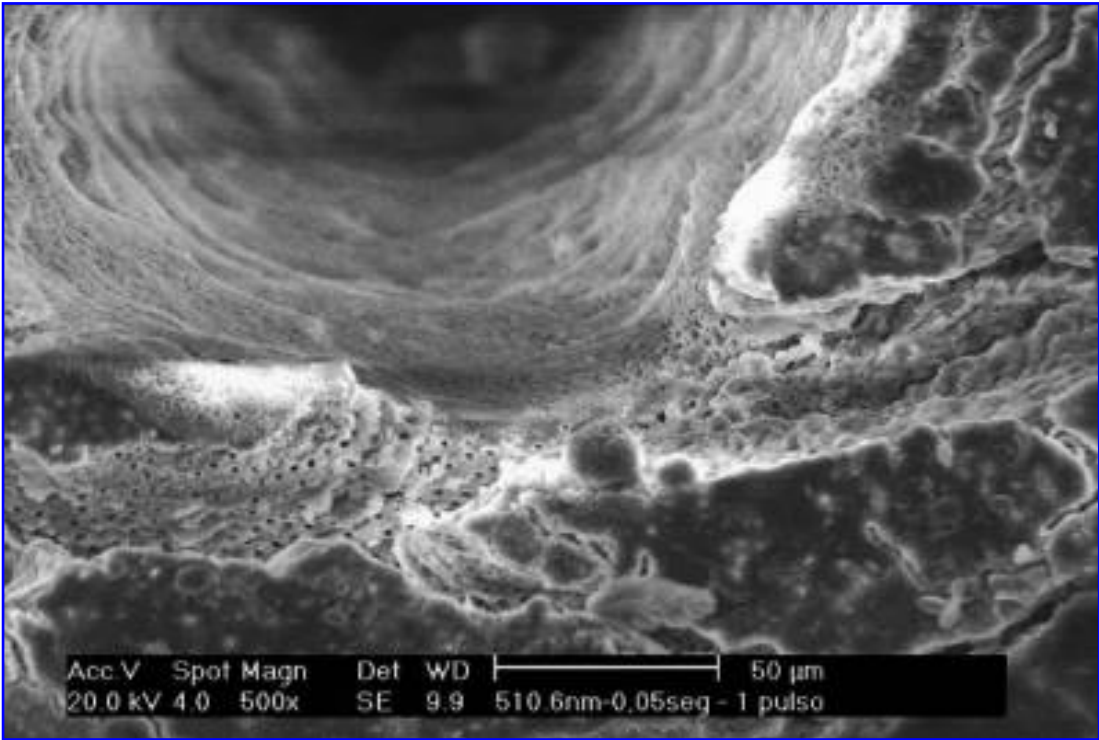
ing the literature, we can confirm that CVL radiation has a sound application on soft tissue in the field of dermatology.

The lasers used currently for treatment on the dentin walls of the radicular canal are CO<sub>2</sub>, Nd:YAG, Ho:YAG, diode, and Er:YAG.<sup>10</sup> With an understanding of the actions of these lasers, we can identify some parallels to the effectiveness of CVL radiation for possible applications in dentistry.

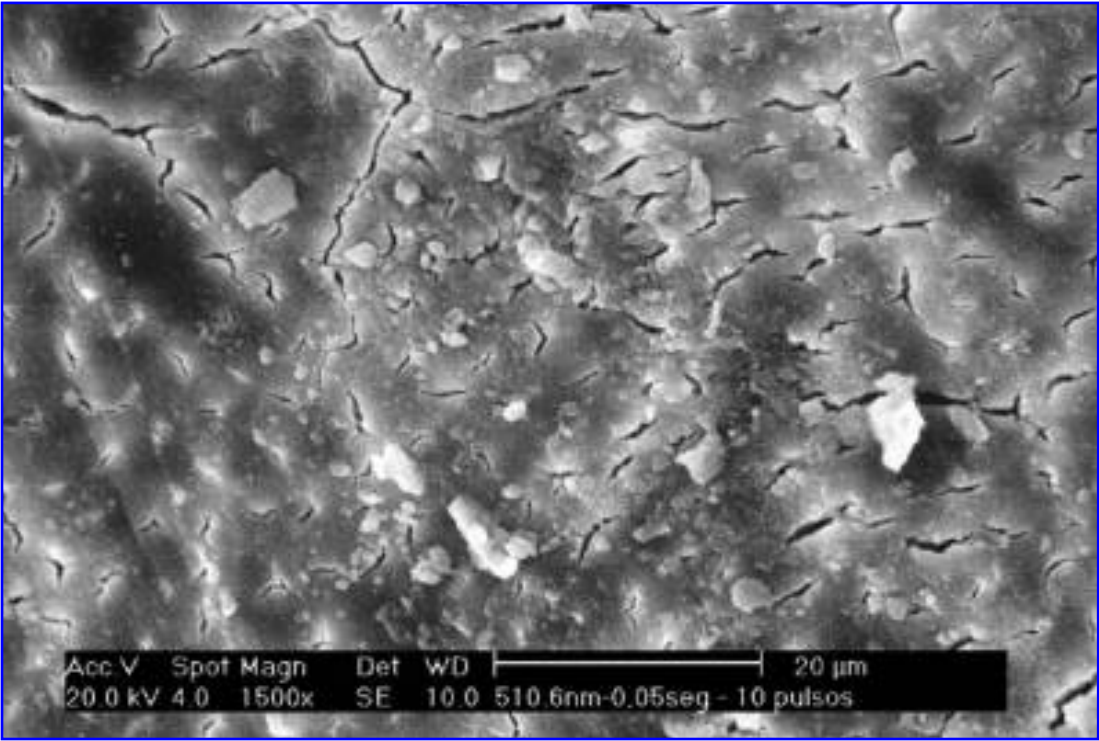
The effects of the instruments and the cleaning methods used on the radicular canals results in the formation of a residual smear layer that is composed of remainders of organic tissue, microorganisms, and rasp of dentin. The presence of organic debris and a smear layer can be an adequate substratum for the growth of microorganisms that remain after the endodontic procedure. When the laser light is exposed to the canal walls, part of the beam is absorbed by the water in the dentin, thus heating the irradiated area to very high temperatures within a short period of time. The amount of energy that is absorbed by the dentin can cause vaporization or fusion as the heat spreads through the tissue. In endodontic therapy, this occurrence results in the opening or closing of the dentinal tubules and the removal of the residual layer of magma, depending on the rate of absorption. Because of the diffusion of the heat, the presence of microbial flora can be reduced.

Goodis et al.<sup>11</sup> used a conventional instrumental technique combined with a Nd:YAG laser and verified that the radicular canals were more effectively cleaned and that the smear layer and remaining organic tissue were removed. Harashima et al.<sup>12</sup> obtained the same results with a Nd:YAG laser applied to the dentin walls of the radicular canal. Their results showed the re-

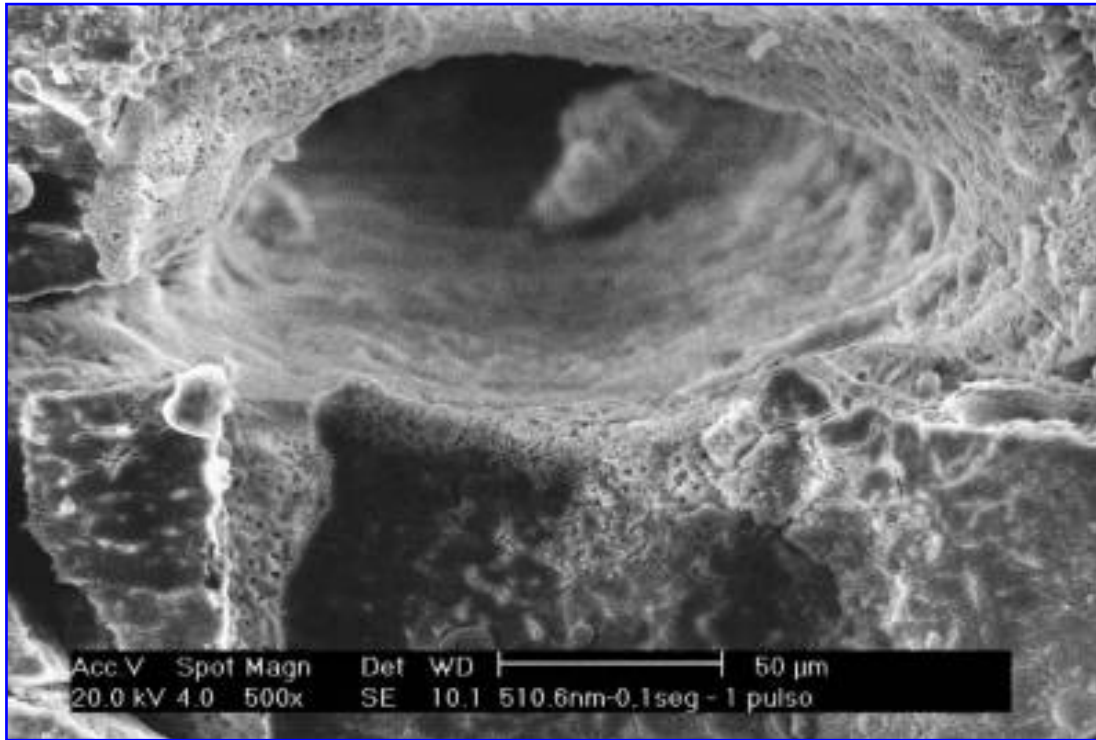




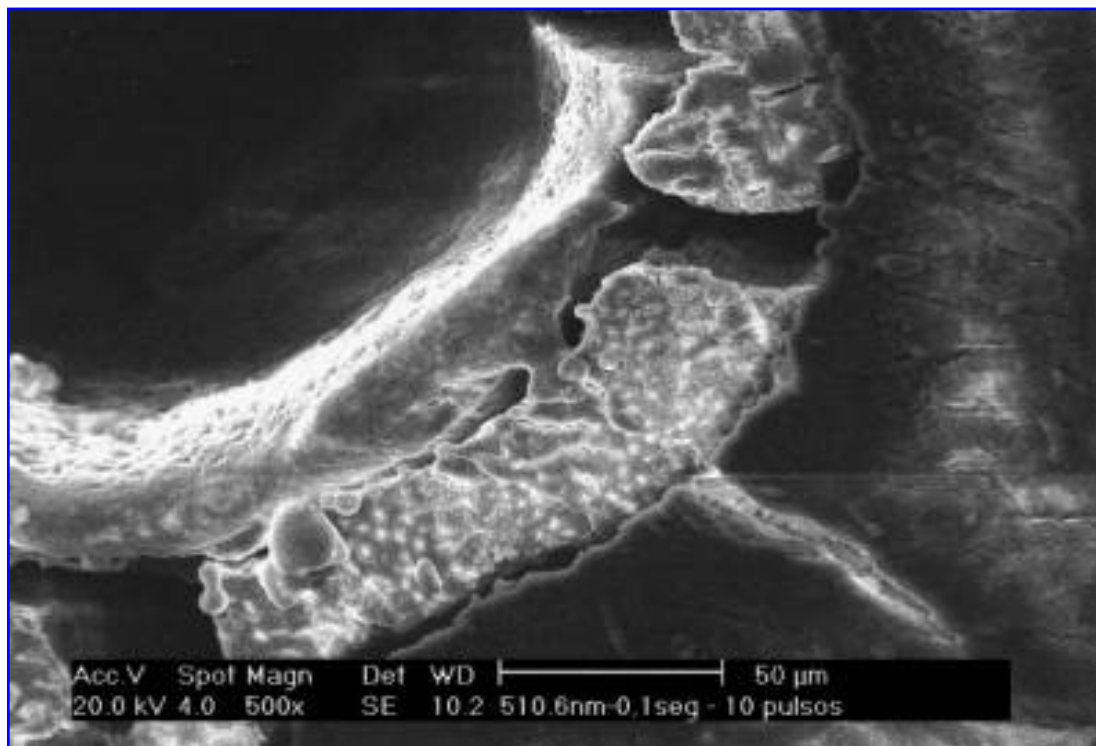
**FIG. 4.** Formation of a deeper cavity showing coalition, cracking, melting, and recrystallization on the affected surfaces (0.05 s/pulse). (500 ×)



**FIG. 5.** Coalition and recrystallization of the dentin wall with cracking and the absence of open dentin tubules. (0.05 s/10 pulses). (1500 ×)



**FIG. 6.** Cavity formation and cracking with fragmented separation, coalition, and recrystallization (0.1 s/pulse). (500 ×).



**FIG. 7.** Total loss of morphology with bridge formation of the fused dentin and recrystallization (0.1s/10 pulses). (500 ×).

removal of the residual layer of magma, with coalition and recrystallization of the surfaces.

Through qualitative (with SEM), and quantitative (with colored infiltration, 2% methylene blue) evaluations, Miserendino et al.<sup>13</sup> noted that the Nd:YAG laser promoted closure of the dentinal tubules and consequently decreased dentinal permeability, allowing for recrystallization of the dentin and producing a surface similar to glass but with a superficial roughness.

Lasers with different wavelengths have varied effects when applied to the same tissue, because the interaction of light with the biological tissue depends on the chromosphere's absorption of that particular radiation. The interaction between the tissue and the laser is also dependent on parameters such as average power, frequency, and exposure time.

Thus, by comparing the effects on the dentin wall of the radicular canal after Nd:YAG and Er:YAG laser irradiation, Tanji et al.<sup>14</sup> concluded that the Er:YAG laser promoted ablation and opened the dentinal tubules, while the Nd:YAG laser closed them by promoting coalition and recrystallization of the dentin.

One of the main concerns regarding the use of lasers in dentistry procedures is the possibility of induction by excessive heating. This can cause irreversible damage to the enamel, dentin, and/or pulp when the temperature is elevated to 10°C above the normal temperature.<sup>15,16</sup>

Bahcall et al.<sup>17</sup> studied the histological effects of a Nd:YAG laser, with an average power of 3 W and a frequency of 25 Hz, on dogs' teeth; they observed that after 30 d there was ankylosis and cement reabsorption. However, Cohen et al.<sup>2</sup> verified that with a Ho:YAG laser, applied at average powers of 0.5, 0.75, and 1.0 W, there was not a significant increase in the temperature of the radicular surfaces when the temperature was increased to 5°C. They also concluded that at this temperature the probability of irreversible damage to the periodontal ligament, cement, and alveolar bone would be minimized. This important aspect has not been further researched at present; however, it will be the subject of future investigation.

Penna<sup>1</sup> completed research using a CVL with a wavelength of 510.6 nm (green) on enamel and dentin. The average power used was 7 W, the repetition rate was 15,000 Hz, the exposure time was 500, 600, and 800 ms and 1 s with a 2-s interval between irradiations. The beam was also directed through a fiber optic device. The author verified that in both the enamel and the dentin, morphologic alterations were not observed at exposure times of 500 and 600 ms, but were at 800 ms and 1 s. Coalition and recrystallization were observed in the dentin, and, at 1 s, coalition was observed in the enamel.

This research verifies that the CVL has the capacity of changing the morphology of human dentin, showing formation of cracks, melting, and cavities on the dentin wall, and coalition and recrystallization of the dentin around the cavity. Future research with this laser is necessary to establish safe parameters that will be adequate for endodontic application without provoking accented thermal implications, on the dentin wall of the radicular canal and consequently affecting surrounding structures with deleterious effects.

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