Journal of Clinical Laser Medicine & Surgery
Volume 15, Number 4, 1997
Mary Ann Liebert, Inc.
Pp. 185–188

The Carbon Dioxide Laser as an Aid in Apicoectomy: An *in Vitro* Study

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ABSTRACT

***Objective:* To achieve the required goal of optimally sealing the apical section and the root-canal when performing an apicoectomy, the authors decided to use the CO_2 laser as an additional aid. *Summary background data:* The CO_2 laser has previously shown to have an excellent sealing effect on dentin surfaces. *Methods:* In this in vitro study, the authors examined the effects of CO_2 laser application in apicoectomies with the help of color penetration tests and scanning electron microscopic (SEM) examinations. Sections and root canals were irradiated with low power (0.5 W) in continuous wave mode for totally 20 sec. The thermal stress for the adjacent tissues attaching thereto is moderate as shown by infrared–spectroscopy. *Results:* A comparison with non-irradiated samples revealed that CO_2 laser irradiation reduced color penetration at the section to a minimum. Also, irradiation of the root-canal wall resulted in satisfactory sealing of the surface. These findings were supported by the results of the SEM examinations. *Conclusions:* CO_2 laser treatment optimally prepares the tooth for final intraoperative filling because of sealing of the dentinal tubules, the resultant elimination of niches for bacteria and the sterilizing effect of the laser.**

INTRODUCTION

When an apicoectomy is performed, it is desirable to achieve optimal sealing of the apical section within the dentin. The seal should cover the root canal, its side canals, and the dentinal tubules exposed during removal of the root tip should be obtained. It, therefore, seems reasonable to use a laser for treatment.

Miserendino[1] performed an apicoectomy with a carbon dioxide (CO_2) laser. He had observed crystallization of root dentin and carbonization of organic material in previous *in vitro* tests. The recrystallized dentin attached weakly to the underlying dental substance and could be easily removed. The remaining stump had a smooth, hard surface, which was highly suitable for retrofilling. The root apex and the root canal were irradiated at 10 W for 20 seconds and 0.5 second, respectively, for sterilization.

Neiburger[2] carried out microscopic, radiographic, and mechanical examinations of various CO_2 laser adjustments for root apex welding. He found that the apical openings of anterior teeth were sealed completely when irradiated with an output power of 15 W for 0.5 second.

Friedman et al.[3] carried out apicoectomies in dogs with the CO_2 laser. They were not able to achieve better results than with conventional treatment. The authors attributed the poor results to the fact that a pulsed laser mode was used (15 W, with a pulse duration of 0.05 second), because not all tubules were sealed. In our opinion, the partial delivery of energy of pulsed lasers in this case is too high and can damage hard tissues, although temperature is not essentially changed integrally.

In *in vitro* studies performed previously by Mortiz et al.,[4] the effects of CO_2 laser irradiation on the root-canal surface were investigated. It was possible to irradiate the entire surface of the root canal by using a specially developed attachment (a rigid hollow waveguide with a diameter of 0.8 mm); an almost complete closure of the dentinal tubules by irradiating the teeth at a power of 0.5 W for 20 seconds was achieved. Organic residues of the pulp tissue were evaporated.

In another study by Moritz et al.,[5] SEM examinations revealed almost complete closure of the dentinal tubules

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after CO_2 laser irradiation of exposed hypersensitive dental necks.

In the present *in vitro* study, therefore, it was decided to use the CO_2 laser as an additional aid in apicoectomies performed on extracted human teeth to seal the apical dentin and to treat the root canals. Subsequently, color penetration and SEM examinations were carried out.

MATERIALS AND METHODS

Sample preparation

A total of 50 extracted human maxillary central incisors was examined. The teeth were stored in physiologic saline solution. The root tips of monoradicular anterior teeth were removed approximately 2 mm above the apex with a Lindemann bur in such a way that all sections had roughly the same diameter (maximum deviation 0.2 mm). A mechanical preparation up to ISO 100 was carried out. This generous preparation was necessary because CO_2 laser treatment of the root-canal lumen requires the use of a rigid hollow waveguide with a diameter of 0.8 mm. The teeth were then subdivided into three groups, two groups consisting of 20 teeth each and one of 10 teeth.

Laser treatment of the apical dentin surface

In the first group, the entire apical section of each tooth was irradiated with the CO_2 laser. The "LASERSAT" device by SATELEC (Merignac, France) was used throughout the study. This laser is a very compact device: the CO_2 laser itself is located in a handpiece, whereas the power and the control units are located in a separate casing. Because the CO_2 laser radiation is within the infrared region, with a wavelength of 10.6 μm, the laser is coupled with an additional low-power He/Ne laser whose red beam allows precise positioning. The power output can be maintained between 0.5 and 5 W, and the radiation is emitted in continuous waves. The sections were irradiated at the lower power output (0.5 W) for 20 seconds while making continuous circular movements with the laser. Five seconds of irradiation were followed by a 30-second pause, followed by 5 seconds of irradiation and so on, until 20 seconds of total irradiation time were achieved. This procedure was chosen to minimize further thermal stress to the adjacent tissues. The irradiated area of approximately 0.2 cm^2 was treated at a fluence of 5×10^{-3} J/cm^2. The use of the above-mentioned hollow waveguide resulted in a spread of the laser beam to a diameter of 0.8 mm; thus the surface can be irradiated homogeneously.

The teeth of the second group were used as nonirradiated control teeth. The teeth of the third group were irradiated after half the section of each tooth had been covered with tin foil. By doing so, it was possible to screen precisely half the apex region from laser irradiation and to assess the effects of laser treatment in one and the same tooth. The teeth were again irradiated at a power of 0.5 W.

Laser irradiation of the root-canal surface

The root canals of the teeth of all three groups were irradiated. Again, the CO_2 laser was used, however, with a specially designed attachment. A mirror reflects the laser beam into a hollow waveguide, which is gold plated on the inside and has a diameter of 0.8 mm. This unit can be easily inserted into a root canal prepared up to ISO 100. We maintained the output power at 0.5 W and irradiated the root canals for 20 seconds in continous wave mode, while performing slow and even movements with the hollow waveguide within the root canal.

Because comparable results of other studies (Moritz et al.[4]) were available, it was not found necessary to use a separate control group of nonirradiated root canals.

Color penetration test

After laser treatment, half the teeth of each group were put into 1% acid-fuchsin solution for 1 hour to compare the permeability of irradiated and nonirradiated dentin in a color penetration test. This results in a typical color pattern, which, depending on the penetration depth and color intensity, permits inferences on the permeability of dentin. After staining, series of longitudinal sections and cross-sections of the teeth were prepared, and the color distribution was examined under a light microscope.

Scanning electron microscopy

All teeth to be examined under the scanning electron microscope were sectioned in the axis of the root canal and prepared for SEM examination.

Infrared spectroscopy

To further assess the impacts of laser irradiation on thermal stress, measurements using an infrared camera with a lateral resolution of 0.1 mm and a thermal resolution of 0.1°C were performed. For this purpose, a lower human incisor (bone impacted) was used that had previously been submitted to apicoectomy. The tooth was irradiated as described above. The measurement was done immediately after the second irradiation period of 5 seconds.

RESULTS

Color penetration test

As far as the teeth irradiated at both the apical section and the root-canal lumen are concerned, there was no color penetration at all—neither at the apical section nor at the root-canal lumen (see Fig. 1).

The group of teeth, which had not been irradiated at the apical section, showed color penetration starting from the section and reaching far into the dentin; however, there was no color penetration from the (irradiated) root-canal lumen (see Fig. 2). The difference between irradiated and nonirradiated dentin is best discernible in the sections, which had been subdivided into irradiated and nonirradiated halves. These sections showed no color penetration from the root-canal lumen or the irradiated portion of the apical section.

Scanning electron microscopic examination

Figure 3 shows a representative section through the irradiated apical dentin. The molten, recrystallized surface is

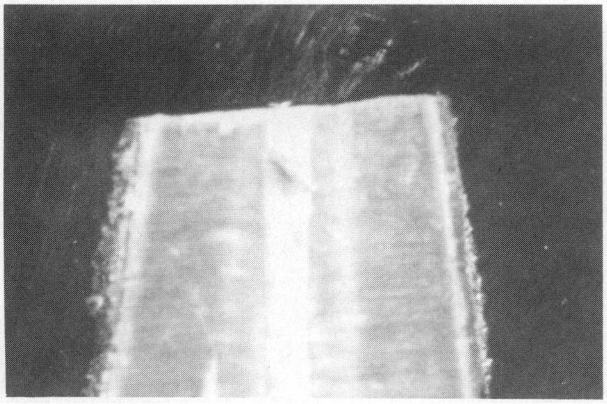

FIG. 1. Longitudinal sectional view of a central incisor under the light microscope. No color (shown as grays here) penetration from the apical section or the root-canal lumen.

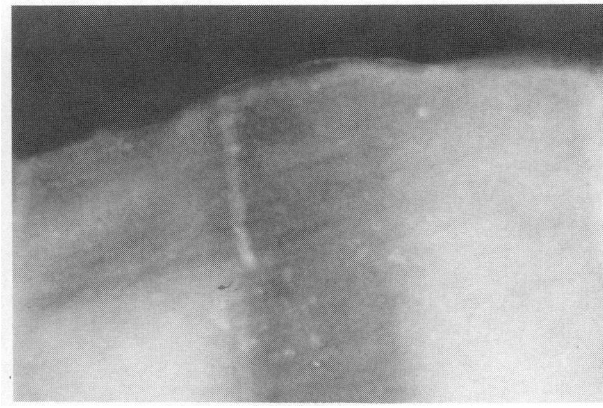

FIG. 2. Longitudinal sectional view of a central incisor under the light microscope. Color (shown as grays here) penetration only from the nonirradiated half of the apical section.

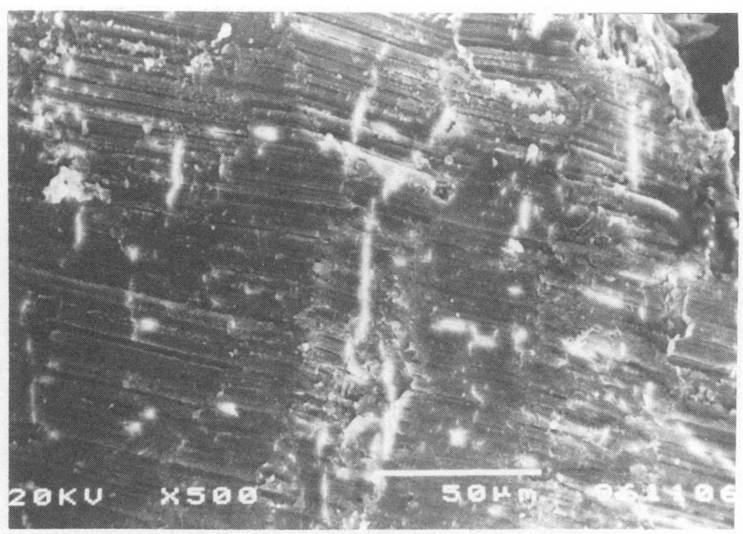

FIG. 3. SEM examination of the irradiated apical dentin.

clearly discernible. The irradiated area appears mostly homogenous.

Infrared spectroscopy

The outcome of the infrared spectroscopy of the irradiated area shows a total increase of temperature of 10°C. In the desmodontal area, maximum temperature increase is 5°C.

DISCUSSION

Unlike the authors mentioned in the Introduction section (Miserendino,[1] Neiburger,[2] and Friedman et al.[3]) who used the laser as a tool for carrying out apicoectomies, we used the CO_2 and neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers as an additional aid in our apicoectomies (which were carried out instrumentally-mechanically). Therefore, our results can be compared with those of the above authors to a limited degree only.

Irradiation of dentin with the CO_2 laser results in a higher resistance to physical and chemical stimuli.[6,7] Stabholz et al.[8,9] found significantly less color penetration in apical surfaces of monoradicular teeth irradiated with the Nd:YAG laser than in control teeth. SEM examinations revealed a molten dentin surface, which resembled glazed, baked droplets. Resolidification and recrystallization of the molten areas, however, seemed to be incomplete and discontinuous.

In their *in vitro* experiments, Dederich et al.[10] observed glazing of dentin surfaces after irradiation with the Nd:YAG laser, resulting in sealed dentinal tubules. Using SEM and color penetration images, Gutknecht and Behrens[11] were able to prove that the root canals were completely freed from pulp tissue and materia alba through irradiation with Nd:YAG laser. The dentinal tubules were almost completely sealed. Recrystallization resulted in a nonporous, glazed surface.

We believe that, given these indications, the CO_2 laser has a more advantageous wavelength, because it is absorbed in water-containing tissues and near the surface,[12] whereas the short-wave infrared light of the Nd:YAG laser is absorbed mainly in pigmented tissue.[13] Moreover, the Nd:YAG laser has a greater depth effect (ie, it requires a higher amount of energy).[12]

Because of the rigid hollow waveguide fitted to the attachment, the CO_2 laser can be used only for treatment of straight root canals; its diameter of 0.8 mm requires a generous preparation of the canal up to ISO 100.

The Nd:YAG laser, whose flexible light guide would allow access to root canals during retrograde preparation, could be used to irradiate root canals with a tight lumen or bent root canals.

As the results of the color penetration tests show, successful sealing of both the apical dentin and the root-canal walls by CO_2 laser irradiation was achieved.

The results of the SEM examinations support these findings. The structural changes in dentin resulting from the sealing process of laser irradiation are clearly discernible.

According to the outcome of the infrared spectroscopy, thermal damage to the adjacent tissues can be excluded.

In our opinion, laser treatment optimally prepares the tooth for final intraoperative filling because of the described sealing of the dentinal tubules, the resultant elimination of niches for bacteria, and the sterilizing effect of the laser.

The findings of this *in vitro* examination indicate that the CO_2 laser is a suitable aid for performing apicoectomies, and they encourage us to use this method *in vivo*.

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