Bactericidal Effects of Er:YAG Laser Irradiation in Root Canals

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Purpose: The aim of this study was to gain information about the antimicrobial effect of Er:YAG laser irradiation on bacteria in dental root canals in vitro.

Materials and Methods: The coronal section of 20 extracted human teeth was removed to enable better access to the canals. All canals were cleaned and enlarged by the conventional method using K-files size 10 to 40. Apical foramens were sealed with fissure sealant. Sterilization of canals followed at 120°C for 15 min. Then 10 canals were inoculated with Streptococcus aureus bacteria and 10 others with E. coli bacteria. All teeth were kept for 2 h at 37°C. After 2 h all canals except the controls were sterilized with the laser set at 15 Hz, 60 mJ energy per pulse for 12 s. The procedure was repeated four times. Material was taken from each canal, incubated for 24 h, and the results analyzed.

Results: A significant reduction of bacterial content was found in the laser-sterilized canals.

Conclusion: Er:YAG laser can be used for sterilization of root canals.

Key words: Er:YAG laser, bacteria, root canal.

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Endodontic treatment consists of pulp extirpation, cleaning, enlarging, and preparing the root canals for a proper endodontic filling in order to seal off the canal from the surrounding oral tissues. Unfortunately, endodontic therapy is not always successful, even if it is performed under the best possible circumstances. The complex morphology of the root canal system makes this procedure more difficult, and may compromise the success of the treatment. A number of studies claim that endodontic treatment of teeth without periapical radiolucency shows best results. On the other hand, teeth with periapical radiolucency demonstrated a very high rate of failure.[1-3]

One of the main reasons for endodontic failure is contamination of root canals and penetration of pathogenic microrganisms into the remaining pulp and periapical tissue. Therefore, besides the mechanical preparation and enlargement of the root canal, elimination of bacteria from the canals by irrigation is recommended. Disinfecting chemicals, such as 5% NaOCl and 2% chlorhexidine gluconate, can be used for this purpose.[4]

The conventional chemomechanical treatment for canal preparation, enlargement, and removal of necrotic soft tissue is not always complete, and neither is bacteria removal. Very often, the apical third of the root canal remains insufficiently prepared, meaning that a smear layer made of dentin debris, pulp residue, and bacteria, may be found in it. Irrigation of the smear layer from the dentin tubules may be impossible, so the need for a new method to make endodontic treatment

easier and more successful resulted in developing sealers for the dentin tubules in the root canal, as well as equipment for canal cleaning and enlargement.

Ever since lasers for dentistry have been available, researchers have been trying to use them in endodontics for root canal sterilization. Many authors have tested the bactericidal efficacy of different types of lasers with varying success. Gutknecht et al conducted a clinical comparison of the antibacterial activity of a high-power diode laser with 5% NaOCl, and showed that diode laser radiation is as effective in disinfecting root canals as irrigation with 5% sodium hypochlorite.[5] One of the laser types often used to kill bacteria is the Nd:YAG laser. Ramskold et al indicated that Nd:YAG laser can be used to sterilize heavily infected root canals if proper settings are used.[6] Rooney used a laboratory model of capillary tubes containing a measured volume of Enterococcus faecalis broth culture to demonstrate the bactericidal effect of the Nd:YAG laser. Doses of 54 J significantly reduced the number of bacteria in the laboratory model.[9] Argon laser also has the power to kill bacteria, as was shown in an in vitro study with root canals infected with Streptococcus aureus, E. faecalis, and Pseudomonas aeruginosa using an undivided lethal dose for 100% kill of bacteria.[7] Mehl used Er:YAG laser to test the bactericidal effect in artificially inoculated root canals from extracted teeth, and confirmed that laser irradiation exhibits very effective antimicrobial properties in root canals, depending on the duration of radiation.[8]

The purpose of this in-vitro study was to investigate the bactericidal effect of the Er:YAG laser on the bacteria in root canals.

MATERIALS AND METHODS

The experiment was conducted under in-vitro conditions. Twenty extracted, intact human teeth were used. All teeth were single-rooted (first mandibular premolar) and had been extracted for orthodontic reasons. Teeth were collected over a period of three months, during which they were stored in saline solution. The coronal part of each tooth was removed to provide full access to the root canals. The pulp was removed and canals were mechanically prepared and enlarged with size 40 Kerr Files. Apical foramens were sealed with fissure sealant to avoid leakage of the material that was later used to inoculate the canals. All teeth were sterilized at 120°C for 15 min. Ten teeth were inoculated with Staphylococcus aureus and 10 more with Escherichia coli. Both groups were kept at 37°C for 2 h. After incubation, all teeth except for the controls were sterilized with Er:YAG laser (KaVo Key, KaVo, Biberach, Germany) using the following parameters: 15 Hz frequency, and 50 mJ energy per pulse. Parameters were chosen according to the manufacturer's recommendations for Er:YAG laser application for root canal sterilization. A specially designed handpiece for endodontics was used for the procedure, together with a specially designed flexible optical fiber which transmitted the laser beam into the canal. The process began by placing the optical fiber near the apex in the root canal, then performing slow, circular movements in the canal for 12 s. The procedure was repeated 4 times in one session. Samples were taken from each canal, inoculated on blood agar, and incubated for 24 h at 37°C. After that, bacterial counts were taken.

RESULTS

Samples taken from the control tooth inoculated with E. coli bacteria showed higher bacterial counts than samples taken from root canals irradiated with the Er:YAG laser, as illustrated in Figs 1 and 2. Similarly, samples taken from root canals inoculated with S. aureus and irradiated with the Er:YAG laser showed lower bacterial counts than the control (Figs 3 and 4). The difference in bacterial count between the samples taken from the control group that was inoculated with E. coli bacteria but not treated with laser, and the group of root canals which were inoculated and treated with the laser, is statistically significant ($p < 0.0001$). The difference in the bacterial count between the samples taken from the control group which was inoculated with S. aureus but not laser irradiated, and the group of canals which were inoculated and irradiated with the Er:YAG laser is also statistically significant ($p < 0.0003$) (Table 1).

DISCUSSION

Previous studies have shown that lasers can be successfully employed in managing infection in root canals by sterilization. Moritz et al conducted a laboratory investigation that included extracted single-rooted teeth.[9] All teeth were inoculated with a suspension of Enterococcus faecalis and Escherichia coli. The decrease in the number of bacterial cells after radiation with the diode laser was highly significant.[9]

With the development of a new solid-state laser, the Er:YAG, a new laser wavelength was made available

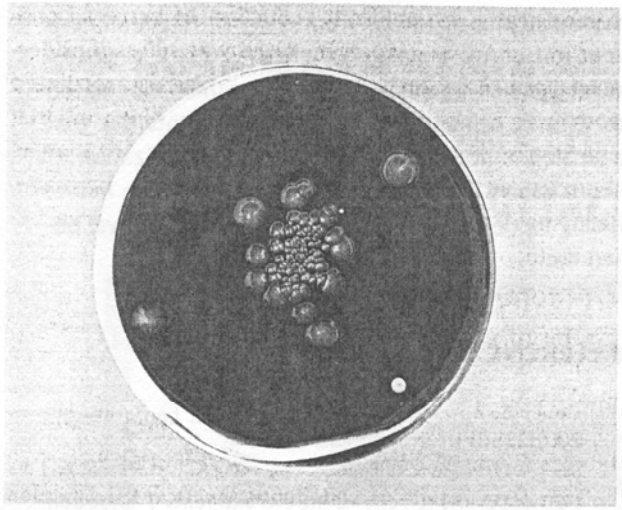


Fig 1 E. coli bacteria count control.

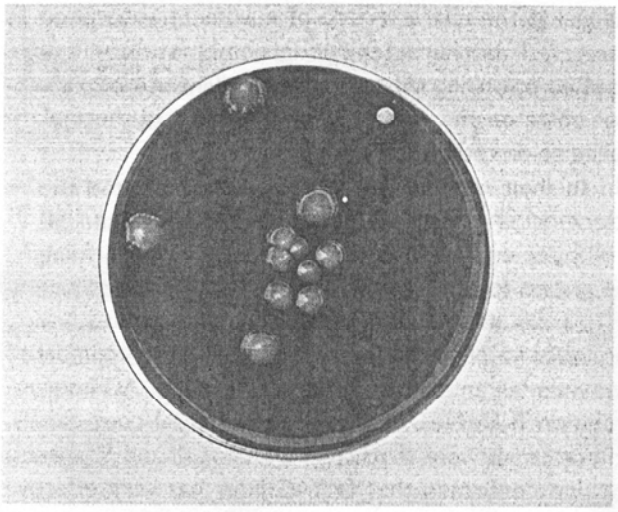
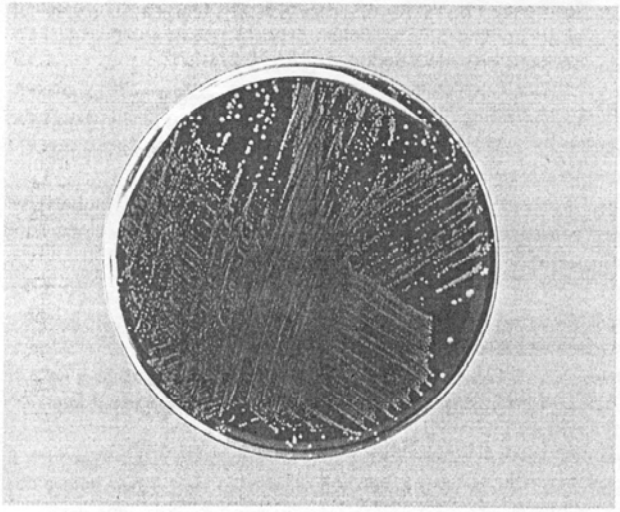


Fig 2 E. coli bacteria count after laser irradiation.



g 3 S. aureus bacteria count control.

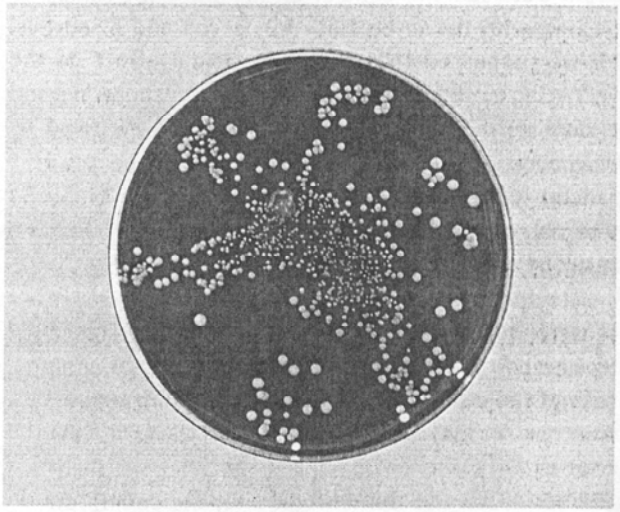


Fig 4 S. aureus bacteria count after laser irradiation.

Table 1 Bacteria counts in control and laser-treated canals.

	control	mean	SD	min	max	p
E. coli	84	18.83	13.32	8	43	0.0001
S. aureus	$>10^6$	25,800	38116.4	50	75,000	0.0003

Min: minimum bacteria count after laser treatment; max: maximum bacterial count after laser treatment.

that has the characteristic of maximum absorption in water. This characteristic in combination with the pulsed operating mode results in excellent material ablation rates on the one hand, and minimal thermal influence on the other.

In their in vitro study, Hibst et al investigated the bactericidal effects of the Er:YAG laser. They used 50 mJ pulse energy and 15 Hz repetition rate, performing 4 phases to accumulate the total dose for sterilization. Their results showed that individual laser pulses have a cumulative bactericidal effect.[10] Mehl et al[8] compared in vitro the antimicrobial properties of Er:YAG laser radiation with NaOCl irrigation in dental root canals. Root canals were inoculated with E. coli and S. aureus. It was confirmed that Er:YAG laser has very effective antimicrobial properties when used in dental root canals, depending on the time of radiation.[8]

Our study showed a significant difference in bacterial count between the control canals and root canals treated with the laser, both for E. coli and S. aureus. Mehl[8] suggested that the bactericidal effect of the Er:YAG laser is due to cellular water evaporating and expanding quickly during the laser pulse, followed by disintegration of the bacterial cell. A second possible reason for reduction of the bacterial count may be thermal necrosis or dehydration that occurs more as a result of the repetition rate than of pulse energy.[8]

Results from our study indicated that E. coli is more sensitive to laser treatment than S. aureus. This could be because of the difference in water content, volume, strength of the cellular wall, and absorption properties. Another reason may be migration of bacteria into the root canal. Different bacterial species have different abilities to invade the dentinal tubules, depending on their morphological factors. Some species of bacteria migrate deeper into the wall of the root canal than others, which give them protection from the laser radiation. Because of the low pulse energy (50 mJ) we used in the root canals, the radiation did not ablate the hard tissue.

CONCLUSION

Er:YAG laser irradiation (15 Hz repetition rate and 50 mJ energy per pulse) used for root canal sterilization demonstrated a significant reduction of bacterial content in our study. However, there was still a considerable amount of bacteria left in the canals inoculated both with E. coli and S. aureus, which points out that one session is not enough for complete sterilization of the root canals. Further investigations should be made, including more sessions (3 or 4) with a rest interval between them.

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