Comparison of Bacterial Reduction in Straight and Curved Canals Using Erbium, Chromium:Yttrium-Scandium-Gallium-Garnet Laser Treatment *versus* a Traditional Irrigation Technique With Sodium Hypochlorite

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Abstract

Introduction: This study compared the reduction of *Enterococcus faecalis* in straight and curved canals using an erbium, chromium:yttrium-scandium-gallium-garnet laser and irrigation with 6.15% sodium hypochlorite (NaOCl). **Methods:** Fifty-five single-rooted extracted teeth were divided into straight and curved canal groups. The root lengths were standardized (14.0 mm) and NiTi instruments were used to prepare the canals to a size #40/0.06 taper. Irrigation was performed with 6.15% NaOCl and RCPrep (Premier Dental Products Co, Plymouth Meeting, PA) as lubricant. The smear layer was removed with 17% EDTA. The samples were sterilized, inoculated with *E. faecalis*, and incubated for 48 hours at 37° in a CO_2 chamber. They were then divided into 7 groups: NaOCl in straight canals (NS); NaOCl in curved canals (NC); laser in straight canals (LS); laser in curved canals (LC); positive control straight canals (PCS); positive control curved canals (PCC); and negative control (NegC). Bacterial reduction was measured by counting the colony-forming units (CFUs) and determining the optical density. **Results:** Groups NS, NC, and LS exhibited bacterial growth in 1 out of 10 samples (10%). In group LC, three out of 10 samples (30%) showed bacterial growth. Kruskal-Wallis showed a statistically significant difference between all treatment groups and the positive controls ($p < 0.001$). Analysis of variance showed a statistical significant difference in optic density between experimental and positive controls. **Conclusions:** Traditional irrigation techniques using 6.15% NaOCl effectively eliminated all bacteria in straight and curved canals. Er,Cr:YSGG laser also effectively removed all bacteria from straight canals. However, in three curved canals, even though there were significant bacterial reductions, they failed to render canals completely free of bacteria. *(J Endod 2010;36:725–728)*

Key Words

Er,Cr:YSGG laser, lasers, root canal disinfection, root canal irrigation, sodium hypochlorite

Bacteria and their byproducts are responsible for triggering and/or perpetuating apical periodontitis (1). Removing bacteria and their harmful byproducts (endotoxins) from the canals should result in the elimination of apical periodontitis. Hence, it has been shown that reducing bacteria from canals before obturation leads to better healing and improved outcomes (2, 3).

The complete elimination of microorganisms from the root canals seems to be an impossible task (4). However, despite the limitations, traditional cleaning and shaping techniques have been satisfactory to make root canal therapy a highly successful procedure (5–9).

Several different new systems such as laser irradiation and photodynamic therapy (PDT) have been developed to improve canal disinfection after the completion of conventional cleaning and shaping endodontic procedures (10, 11). However, the effectiveness of these "new devices" has been evaluated mostly in straight canals. Although many teeth requiring root canal therapy have straight canals, teeth with curvatures are also commonly encountered, and they represent a challenge to clinicians because the removal of infected pulp tissue and bacteria can be more difficult in these cases (12).

Sodium hypochlorite (NaOCl) has been the most commonly used irrigation solution in endodontics since early 1900s. It is used alone or in combination with a chelating solution to reduce bacteria and eliminate smear layer (13). However, there is still controversy regarding which concentration of the solution would be most efficacious against the microorganisms and still safe for the patient (14). Chlorhexidine gluconate has also been suggested for root canal disinfection. However, when compared with NaOCl, the former presents only similar antibacterial properties and has no tissue-dissolving capabilities (15).

PDT is another technique that has shown efficacy improving canal disinfection. The elimination of the microorganisms with this technique is achieved by the reaction of a photosensitizer and a light source, producing free radicals capable of damaging and killing bacterial cells. Thus, PDT combined with conventional root canal therapy has afforded greater bacterial reduction than conventional root canal therapy *in vitro* (11). Studies have provided very useful information about treating straight canals.

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However, disinfection of curved canals needs further investigation. Canal curvature and apical diameter influence the mechanical efficacy of root canal irrigation. Irrigation is significantly less effective in curved canals with a small apical diameter than in curved canals with a larger apical diameter (12).

Since the introduction of the laser in endodontics in 1971 (16), several authors have investigated different lasers for use during root canal therapy. The erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser has a 2790-nm wavelength delivered by flexible fiberoptic tips. Thus, "this laser wavelength has highest absorption in water and high affinity to hydroxyapatite," which makes it suitable for use in root canal therapy (17).

Lasers have the ability to clean and effectively disinfect root canals, including eliminating highly resistant species such as *Enterococcus faecalis* (10, 18–20). Furthermore, Noiri et al (21) have shown *in vitro* the efficacy of the Er:YAG laser irradiation against six different biofilm-producing species and concluded that the laser may be an adequate auxiliary tool for canal disinfection in endodontics. Lasers also allow obturation of greater numbers of lateral canals, isthmuses, and accessory canals when compared with traditional cleaning and shaping techniques (22).

However, to the best of our knowledge, no study has directly compared the use of lasers and traditional irrigation techniques using sodium hypochlorite in curved canals. The use of lasers may be a novel method to eliminate bacteria from curved canals and may prove to be more effective than traditional techniques. Therefore, the purpose of this study was to compare bacterial reduction in straight and curved canals using laser treatment versus a traditional irrigation technique.

Materials and Methods

Fifty-five single-rooted extracted human teeth were used in this study. The degree of root curvature was determined for each tooth using the Schneider method and separated into two groups: (1) straight and (2) curved (20°-40°). The teeth were stored in tap water during the collection process.

The teeth were decoronated using a diamond disc to produce a standard root length of 14.0 mm. The canals were enlarged coronally using Gates Glidden drills from size 4 to 2. The working length (WL) was set at 13 mm, 1 mm short of the anatomic apex. All teeth were instrumented to the WL using stainless steel K-files to a size #20 followed by Protaper NiTi instruments (Dentsply Maillefer, Tulsa, OK) up to size F2. The apical preparation was then completed to a master apical file of #40/0.06 using Profile instruments (Dentsply Maillefer). Copious irrigation with 6.15% sodium hypochlorite (NaOCl; Clorox Professional Products, Oakland, CA) was used throughout the instrumentation, and RC-Prep (Premier Dental Products Co, Pennsylvania, PA) was used with each successive file. The canals were left flooded for 3 minutes with 17% EDTA (Henry Schein, Melville, NY) at the end of the cleaning and shaping procedures to remove the smear layer and then rinsed with 3.0 mL of 6.15% NaOCl. The final flush was performed with sterile water. All canals were dried using air and sterile paper points, and the teeth were placed individually in sterilizer pouches, autoclaved at 121°C for 20 minutes, and stored until use.

The teeth were randomly subdivided into one of seven different treatment groups: NS group, straight canals treated with 6.15% NaOCl ($n = 10$); NC group, curved canals treated with 6.15% NaOCl ($n = 10$); LS group, straight canals treated with laser ($n = 10$); LC group, curved canals treated with laser ($n = 10$); PCS group, straight canals positive control ($n = 5$); PCC, curved canals positive control ($n = 5$); and NegC, negative control ($n = 5$).

All teeth were inserted in an upright position in the holes of a sterile pipette rack and placed in a sterile tray filled with trypticase soy broth such that only the apical 2 to 3 mm of the teeth were immersed in the solution. Cultures of *E. faecalis* (American Type Culture Collection [ATCC] 29212) were prepared for inoculation into the sterilized canals of each tooth except for the negative controls. The bacterial suspensions were inoculated using a sterile syringe and a 30-G irrigation needle (Max-i-Probe; Dentsply Rinn, Elgin, IL) measured at 13 mm. After inoculation, all teeth were incubated at 37°C in a CO_2 chamber to allow growth of *E. faecalis* biofilm for 48 hours.

A standardized irrigation protocol was used and then compared with the laser. The needle tip was placed at the WL, and 3 mL of 6.15% NaOCl was delivered over a period of approximately 1 minute. A piece of wax was placed at the tip of the root to prevent irrigant from flowing out the apex and to promote the flushing action. A final flush with 3 mL of sterile distilled water was performed to inactivate the NaOCl.

In the Er,Cr:YSGG laser group (Waterlase MD; Biolase Technology, Inc, San Clement, CA), a RFT2 (0.27 mm in diameter) side-firing fiberoptic tip (RFT2 Endolase, Biolase Technology, Inc) was placed at the WL (13 mm), activated, and slowly withdrawn from the canal over a 10-second interval. It was used three times against each wall (mesial, distal, buccal, and lingual) for a total of 12 laser insertions made per canal (2 minutes total per canal). The following settings were used: 0.75 W (calibration factor for the tip = 0.55), 20 Hz, 10% air, and no water, according to the manufacturer instructions for canal disinfection. The positive controls were not treated.

After treatment, sterile Ringer solution was placed in all canals, and sterile paper points were inserted at the WL and left for 15 seconds to soak up the contents of the canals. The wet paper points were then dropped into sterile Eppendorf tubes with Ringer solution and sonicated for 20 seconds to free the bacteria. Serial dilutions were performed to a concentration of 10^{-6}. Dilutions from 10^{-4} to 10^{-6} were plated on blood agar and incubated at 37°C in a CO_2 chamber for 48 hours. The plates containing between 30 and 300 colonies were counted. The mean number of CFUs and optic density for the 10^{-5} dilution plates were then calculated, and the results were statistically analyzed by using Kruskal-Wallis and analysis of variance tests. The significance level was set at $p \leq 0.05$.

Results

Table 1 shows a summary of the results. All of the positive control teeth exhibited bacterial growth, whereas none of the negative controls

TABLE 1. Summary of CFU Counts and Optic Density for the Experimental and Control Groups

	NS	NC	LS	LC	PCS	PCC	NegC
# w/growth	1/10	1/10	1/10	3/10	5/5	5/5	4/5*
CFU (mean)	0.00	0.00	1.00	15.90	102.20	109.00	0.00
OD values (mean)	0.306	0.377	0.234	0.407	0.762	0.795	0.00

CFU, colony-forming units; LC, laser in curved canals; LS, laser in straight canals; NC, NaOCl in curved canals; NegC, negative control; NS, NaOCl in straight canals; OD, optic density; PCC, positive control curved canals; PCS, positive control straight canals.

*One sample was lost because of extraneous contamination.