Temperature Changes Accompanying Near Infrared Diode Laser Endodontic Treatment of Wet Canals

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Abstract

Introduction: Diode laser endodontic treatments such as disinfection or the generation of cavitations should not cause deleterious thermal changes in radicular dentin. **Methods:** This study assessed thermal changes in the root canal and on the root surface when using 940 and 980 nm lasers at settings of 4 W/10 Hz and 2.5 W/25 Hz, respectively, delivered into 2000-μm fibers to generate cavitations in water. The root surface temperature in the apical third was recorded, as was the water temperature in coronal, middle, and apical third regions, by using thermocouples placed inside the canal. Lasing was undertaken with either rest periods or rinsing between 5-second laser exposures. **Results:** Both diode lasers induced only modest temperature changes on the external root surface at the settings used. Even though the temperature of the water within the canal increased during lasing by as much as 30°C, the external root surface temperature increased by only a maximum of 4°C. Irrigation between laser exposures was highly effective in minimizing thermal changes within the root canal and on the root surface. **Conclusions:** Diode laser parameters that induce cavitation do not result in adverse thermal changes in radicular dentin. *(J Endod 2010;36:908–911)*

Key Words

Diode, endodontic treatment, lasers, temperature, thermocouples

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Diode lasers can be used as an adjunct for root canal disinfection (1–11). The 940 and 980 nm wavelengths are of interest, because absorption in water makes these suitable for generating cavitations in aqueous fluids when these lasers are used in pulsed modes (12). Laser-generated cavitations might assist in removing debris and smear layer from root canals (13, 14).

Because both disinfection and cavitations arise from photothermal interactions, it is essential to evaluate thermal stress to the external root surface, because this dictates whether injury to periodontal ligament cells and alveolar bone occur (4, 15–18). The threshold for this is a temperature increase of 10°C for less than 1 minute for bone and periodontal ligament (19).

Photothermal effects are influenced by wavelength, power density, irradiation mode, duration of exposure, and dentin thickness (20, 21). The apical region of the root canal system is more prone to thermal insult because the thickness of dentin is least in this region (17), and the end of the fiber will pass very close to the canal walls because of anatomical constrictions. To minimize thermal effects during endodontic laser treatments with plain fibers, the fiber end should be moved constantly in a circular motion during activation and withdrawn (6). Such movements are more easily achieved with thin flexible fibers (11).

The aim of this study was to assess thermal changes on the root surface and within water inside the root canal by using 940 and 980 nm wavelength lasers under conditions shown previously to induce cavitations in water inside root canals (12).

Materials and Methods

Laser Systems

The Ezlase 940 nm wavelength diode laser (Biolase, San Clemente, CA) was used at a panel setting of 4 W/10 Hz, which gave an actual laser power of 1.68 W from the terminal end of a 200-μm diameter plain-ended endodontic fiber. The Sirolaser 980 nm wavelength diode laser system (Sirona, Bensheim, Germany) was used at a panel setting of 2.5 W/25 Hz, giving an actual measured laser power of 1.35 W from a 200-μm diameter plain-ended endodontic fiber. For both lasers, the parameters used were the lowest that cause cavitation to occur in water within a 5-second period (12). For both lasers, the fiber terminus was cleaved between experimental runs.

Sample Preparation

A total of 29 single-rooted extracted teeth that had been stored in distilled water with 1% thymol were used. These comprised equal thirds of maxillary incisor, second premolar, and canine teeth, which were allocated randomly to treatment groups. Teeth were sectioned horizontally at the cementoenamel junction by using a diamond disk, and the crowns were discarded to enable direct access to the root canals, which were 9–13 mm in length. Patency of the apical foramen was confirmed with an 80-μm diameter K-file passed in a retrograde manner. After extirpating remnants of the dental pulp, the penetration of the laser fiber was checked, and the coronal third was enlarged with hand K-files as needed to allow passive insertion. Each root was fixed in place on a positioning jig with molding wax. The root canal was filled with distilled water before the laser fiber was placed in its starting position 2 mm short of the anatomical apex.

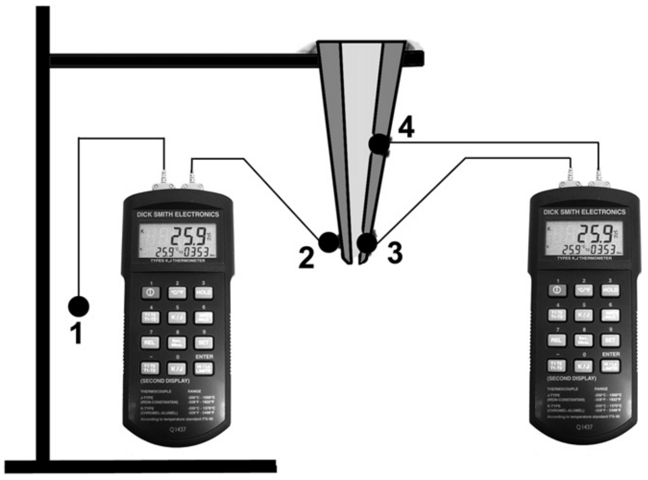

Figure 1. Schematic illustration of the experimental setup in part 3 of the study for simultaneously measuring ambient temperature (1), root surface temperature in the external apical third region 1 mm from the anatomical apex (2), water temperature in the apical third of the canal 1 mm from the anatomical apex (3), and water temperature in the middle third of the root canal (4) by using miniature K-type thermocouples and digital thermometers. A single root sample is shown in cross section. Patency of the openings made in positions 3 and 4 was confirmed by microscopic examination before the sensors were sealed into place. The working lengths of the roots used varied from 9–13 mm, and their thickness at the point where the apical third thermocouple was placed 1 mm from the apex was from 0.9–1.5 mm (mean 1.14 ± standard deviation 0.18).

Temperature Measurement

All experiments were carried out at an ambient temperature of 25°C, with distilled water at the same temperature filling the root canals or used as an irrigant between exposure runs. K-type bead thermocouples (diameter, 0.5 mm) were connected to digital thermometers (model Q1437; Dick Smith Electronics, Sydney, Australia), allowing temperature measurement to ±0.1°C. Baseline temperatures immediately before laser activation and the maximum temperatures during laser activation and subsequent cooling periods were recorded for each run, and the differences were calculated. Thermocouples fixed into position on the external root surface 2 mm from the anatomical apex were used to record root surface temperature. Silicon heat conducting paste was used to improve heat conduction from the root surface to these surface-mounted thermocouples.

The study consisted of 3 independent experiments with repeated measures design, each of which used different samples, and was subjected to separate statistical analysis.

Part 1: Comparison of Thermal Changes on the External Surface

Ten root samples were prepared, the laser fiber was placed into position, and the laser then was activated for 5 seconds. During lasing, the fiber was moved in a circular motion and withdrawn coronally at 1 mm/s, such that only the apical third was irradiated. Root surface temperatures were recorded. All samples underwent treatment with both lasers to allow paired comparisons to be made, which were independent of the effect of dentin thickness.

Part 2: Coronal Water Temperature

The canals in 14 roots were prepared by using the crown-down technique, with an apical stop 350 μm in diameter located 1 mm from the anatomical apex. The laser fiber was placed into position, and a single thermocouple was positioned beside the fiber in the coronal third and 1 mm from its distal end, so that there was no direct exposure. The fiber was held in a fixed position, and the laser then was activated for 5, 10, 15, or 20 seconds. A rest period of 5 minutes was allowed between each exposure run to ensure that the roots had returned to their baseline temperature. Fresh distilled water was flushed into the canals before each irradiation sequence to restore the water volume in the root canal, because some fluid was ejected coronally by the pressure waves of the cavitational action. As before, each tooth was treated with both lasers.

Part 3: Internal Water Temperature *versus* External Root Temperature

Five roots were prepared and then modified to allow direct measurement of the internal water temperature in the middle and apical thirds. Cavities that penetrated through the root were prepared, so that thermocouples could be placed flush to the canal wall and did not hinder movement of the fiber within the root canal (Fig. 1). Molding wax was used to seal these in position from the rear and to prevent water leakage. A third thermocouple was located on the external root surface in the apical third region, 1 mm from the anatomical apex, immediately opposite the internal thermocouple. The 980 nm diode laser was used at 2.5 W/25 Hz, with the fiber end 1 mm short of the working length. When the laser was activated, the fiber was held in position apically for 2 seconds and then moved coronally in a circular movement for 3 seconds to give a total laser activation cycle of 5 seconds. This was repeated 4 times, with increasing resting times (5, 10, or 15 seconds) until the next exposure. During the resting period, the canal was flushed with 1 mL of distilled water that was at room temperature.

Data Analysis

All data sets were assessed for normality by using the Kolmogorov-Smirnov test. In the first part of the study, where normal distributions existed, the paired *t* test and Tukey-Kramer repeated-measures analysis of variance with post tests were performed. Data sets in parts 2 and 3 that were not normally distributed were analyzed by using Wilcoxon matched pairs signed rank test and the Friedman test with Dunn multiple comparison tests for post hoc comparisons.

Results

In the first part of the study, measured thermal changes on the external surface of the apical third of the root with both laser wavelengths were small, with mean temperature increases of 2.26°C and 6.47°C for the Ezlase and Sirolaser, respectively. The latter was significantly higher than the former (P = .00001). There was a significant inverse linear association between thermal stress and root dentin thickness measured 1 mm from the apex (R = –0.71, P < .02).

In the second part of the study, only modest increases in coronal water temperature were seen with both lasers, with a linear dose response as laser exposure time increased (Fig. 2). There was no significant difference between the 2 lasers at any exposure time. The highest coronal water temperature increase recorded was 4.4°C after a 20-second irradiation period.

For the third part of the study, typical results for changes in external and internal temperatures after a 5-second laser exposure are shown in Fig. 3. Temperatures internally rose rapidly by as much as 30°C while the fiber tip was passing the thermocouple and then fell sharply almost by the same extent during irrigation. Differences in temperature between the 3 locations were significant at all time points (P < .0001). Even though there were large fluctuations in the