Photomedicine and Laser Surgery
Volume 23, Number 1, 2005

Pp. 10–14

Pulpal and Periodontal Temperature Rise during KTP Laser Use as a Root Planing Complement *in Vitro*

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ABSTRACT

Objective: **The purpose of this study was to define the optimal irradiation conditions of a KTP laser during root planing treatment.** ***Methods:*** **The surfaces of 60 single-root human teeth were scaled with conventional instruments before lasing. The pulpal temperature increase was measured by means of one thermocouple placed in the pulp chamber and a second one placed on the root surface at 1 mm from the irradiation site. The influence of variables of coloration by Acid Red 52 (photosensitizer), scanning speed, dentin thickness, and probe position was analyzed for a constant exposure time of 15 sec and 500 mw (spot size diameter, 0.5 mm). The pulpal temperature was below 3°C for the adjustments.** ***Results:*** **The irradiation on one point of root surface had the following results: The application of photosensitizer on the root surface before lasing produced a 50% higher temperature rise within the pulp than in the case without the application of the photosensitizer. The temperature rise in the pulp chamber was below 3°C with the following settings of 500 mw: PW = 10 msec and PRR < 35; or PW = 20 msec and PRR < 20 Hz. On the other hand, for the same irradiation conditions, the temperature rise on the surface of the root was always below 7°C. However, the temperature increase became higher than 7°C (on the surface of the root) in the case of P > 500 mw, PW > 50 msec and PRR > 10 Hz of root surface or a scanning speed of irradiation of 1 mm/sec for a linear irradiation of 4 mm.** ***Conclusion:*** **The KTP laser may be used safely without thermal damage to pulp and periodontal tissue with respect to the biologically acceptable previously described parameters.**

INTRODUCTION

PREVIOUS WORK demonstrated interest in the use of KTP laser in medicine for several applications: middle-ear surgery,[1] photoselective vaporization of the prostate,[2] endoscopic nasal sinus surgery,[3] anticancer effect,[4] lacrimal duct surgery,[5] mucosal reconstruction using an artificial dermis after KTP laser surgery,[6] treatment of spider leg veins,[7] treatment of telangiectasia,[8] treatment of facial angiofibromata,[9] hemangioma,[10] treatment of tattoos,[10] laser therapy against bleeding,[11] treatment of recalcitrant viral warts,[12] neurosurgery,[13] and aesthetic facial surgery.[14] Other studies have examined the effect of laser irradiation at a variety of wavelengths on the temperature rise of dental pulp.[15–21] The use of laser beams as a complement of root planing has been studied in several works.[22–26] Some studies demonstrated the sterilization effect of lasers in root canal and in periodontic bone pocket.[27–36] However, the use of KTP laser beam in dentristry and especially as a root planing complement may be of some interest because, after conventional scaling, it might be ideal to sterilize the root surface without pulpal damage, especially in the case of chronic infection with bone defect and pocket formation. Before any eventual clinical use, it is wise to define the safety parameters and harmless irradiation conditions for the use of KTP laser beam in order to avoid any overheating of vital tissues. The aim of this study was to define the optimal conditions of irradiation on root surfaces of teeth without raising the temperature of the pulp or the desmodont above a critical temperature. Accordingly, different parameters were explored using a KTP laser.

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MATERIALS AND METHODS

Selection and preparation of teeth

Sixty single-rooted human teeth, recently extracted (because of periodontal reasons), were used. The teeth were scaled with conventional dental instruments. The root canals were prepared and enlarged to no. 60 (K file) in order to allow the penetration of a 0.5-mm-wide probe of the thermocouple in the root canal to the working length (using a rubber stop) (Fig. 1, probe 1). The thermocouple probe was then inserted to verify easy insertion before the experiments. The teeth were then stored before the experiments at 4°C, in a humid atmosphere, on gauze soaked with Hepes solution (Merck; pH 7.2 at 2 mmol/L containing 0.19 mmol/L of natrium azide). At the time of the experiment, the photosensitizer (Acid Red 52) was placed on the surface of the roots before lasing and a thermo-conductor paste (Prosilican thermal compound: warm Leitpaste WPN 10, Austerlitz electronic, Nürnberg 1, Germany) was injected with a Lentulo compactor to complete filling of the canal prepared for the probe, thereby ensuring that maximum thermal conduction was obtained between the sensor tip of the thermocouple probe and the dental tissue. The thermal conductivity of the paste amounted to 0.4 cal • sec^{-1} • K^{-1}, which is in the same order of magnitude of the thermal conductivity of soft tissues (0.2–0.5 cal • sec^{-1} • m^{-1} • K^{-1}, depending on hydratation).[37] After reinsertion into the tooth (using a rubber stop), the position of the probe was radiographically checked. The opening of the root canal was sealed with hot wax around the probe, preventing the movement of the tip of the probe. To also measure the temperature rise on the external side (surface) of the root, a second probe of a thermocouple was placed very close, beside the site of irradiation (Figure 1, probe 2). On the site of the root surface designated to be in contact with the probe 2, the thermo-conductor paste was spread before setting the probe on the root to optimize contact of probe 2 and the root surface.

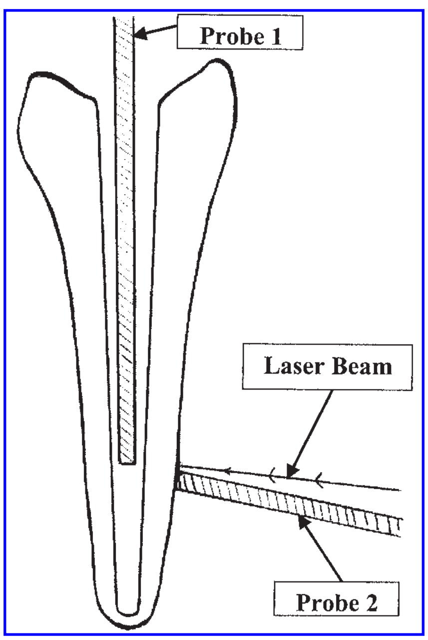

FIG. 1. Schematic presentation of tooth preparation for temperature rise measurements during laser irradiation on root surface. The probe 1 is in close contact with the internal side of the root canal. The probe 2 is also in close contact with the external surface of the root and closed to the lasering site.

Thermocouple

A "fast response" Thermocoax thermocouple (Phillips) made of chrome-alumel (type K) with a 0.5-mm-diameter probe and sensitive to temperature variations between −200°C and 1300°C was used. The accuracy of the thermocouple was ±0.1°C. In order to check the reproducibility of the contact of the probe with the tooth, laser irradiation experiments were repeated after removal and replacement of the probe on the root surface. The temperature rises were then recorded. It was concluded that the error caused by irreproducibility of probe contact did not exceed the error due to the thermocouple itself (0.1°C).

Experimental set-up for temperature registration during laser irradiation

The measurements of the temperature rises at the tooth during the irradiation with the KTP laser were done in digitizing mode: every 0.5 sec, the temperature was measured for a predefined span of time (e.g., 3 min). Using the external trigger of the voltmeter, it was possible to initiate the beginning of the temperature measurements by means of a trigger signal derived from the foot switch of the laser. Consequently, the irradiation and the registration of the temperatures started simultaneously once the foot pedal was pressed. A Macintosh computer equipped with an external interface Iotech–Mac 488A-IEEE IEEE-488 was used to automate the measurements and to process the measurement data. The temperature rise values were written in Mat lab.

Laser

The KTP apparatus was a Ceralas G2 (CeramOptec GmbH, Bonn, Germany). The wavelength output was 532 nm. The conditions and variables used were output power of 50 mw to 2 Watts, pulse width (PW) of 10–2550 msec, pulse repetition rate (PRR) of 20–100 Hz, and spot size diameter of 5 nm. In order to be most efficient and to simulate clinical work, a standard 15-sec continuous lasing was used. To avoid dentin damage by laser irradiation, we decided to concentrate our experiments on low-power irradiation. Two other irradiation parameters were introduced: first, irradiation on one point of the root surface (spot size diameter of 0.5 mm) for 15 sec with and without photosensitizer application, and second, a linear irradiation of 4 mm in length (four times back and forth, spot size diameter of 0.5 mm) on the root surface for 15 sec with photosensitizer application.

For each parameter (e.g., P_1) and tooth, a series of three to five records (t_1–t_5) of temperature rise were taken from the internal probe and the same number of records from external probe. The results of these measurements were used for the calculation of the average (A_1–A_n) of the temperature rise recorded on each tooth for the same parameter as shown in Table 1. The different averages coming from different teeth for the

TABLE 1. AN EXAMPLE OF CALCULATED MEAN AND SD FOR EACH PARAMETER

Calculation of mean and SD per parameter	*Selected parameter (P_1)*	*Recorded temperature (t_1°C)*	*Recorded temperature (t_2°C)*	*Recorded temperature (t_3°C)*	*Average (t°C)*
Tooth 1	P_1	1.7	1.67	1.78	A_1 = 1.716°C
Tooth 2	P_1	1.98	2.05	1.85	A_2 = 1.960°C
$Tooth_n$	P_1	2.01	1.88	1.92	A_n = 1.936°C
Mean and SD for P_1					(A_1, A_2, . . . A_n) = M + SD

same parameter (A_1–A_n) were used to obtain the general mean and standard deviation per paramenter as shown in Table 1. A total of 1266 records were performed in this work. The mean values and standard deviations of temperature were plotted on different graphs.

RESULTS

Irradiation on one point of root surface for 15 sec with and without photosensitizer application

The application of the photosensitizer (Acid Red 52) on the root surface before lasing produced, within the pulp, a higher temperature rise, of 50% (3.63 ± 0.29°C), than in the case without application of the photosensitizer (1.72 ± 0.31°C) at the following setting: 500 mw, PRR = 70 Hz, and PW = 20 msec. In Figure 2, we show an example of pulpal temperature increase with and without photosensitizer.

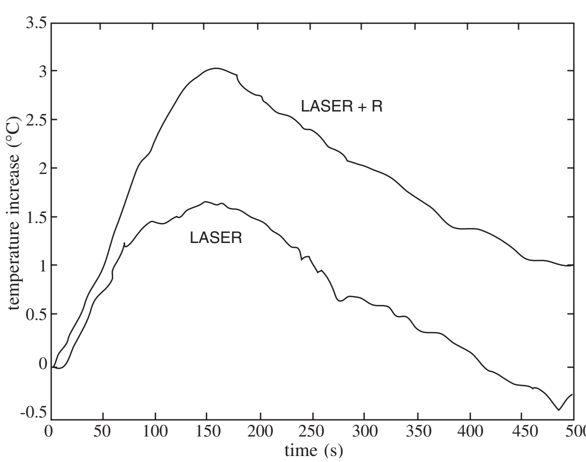

FIG. 2. For the same irradiation conditions, the temperature rise after lasering with application of the photosensitizer (acid red 52) (Laser + R) is higher than the temperature increase in case of lasering without application of photosensitizer (Laser). The irradiation setting was 500 mw; PRR = 70 Hz; PW = 20 msec.

Irradiation on one point of root surface for 15 sec with photosensitizer application

We considered the pulpal temperature rise of 3°C as a maximum of temperature rise that pulp can tolerate without irreversible pulp damage.[38] The results pointed out that the temperature rise in the pulp chamber was still below 3°C with the following settings of 500 mw: PW ≤ 10 msec and PRR ≤ 30 or PW ≤ 20 msec and PRR ≤ 20 Hz (Fig. 3). On the other hand, for the same irradiation conditions, the temperature rise on the surface of the root was always below 7°C, considered acceptable from a biological point of view for the periodontal surrounding tissues[39] (Fig. 4).

However, the temperature increase became higher than 7°C (on the surface of the root) in the case of P > 500 mw, PW ≥ 50 msec, and PRR ≥ 10 Hz.

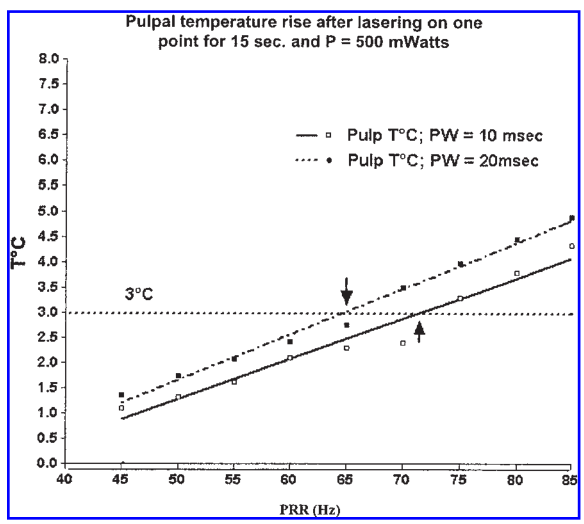

FIG. 3. Linear regression representing the pulpal temperature rise (T°C) in function of the pulse repetition rate (PRR). The pulpal temperature rise depends on the pulse width value and the pulse repetition rate (PRR in Hz). For an output power of 500 mw and to stay below 3°C of pulpal temperature rise, the irradiation setting is PRR ≤ 30 Hz for PW ≤ 10 msec. For PW ≤ 20 msec, the PRR must stay at ≤20 Hz.

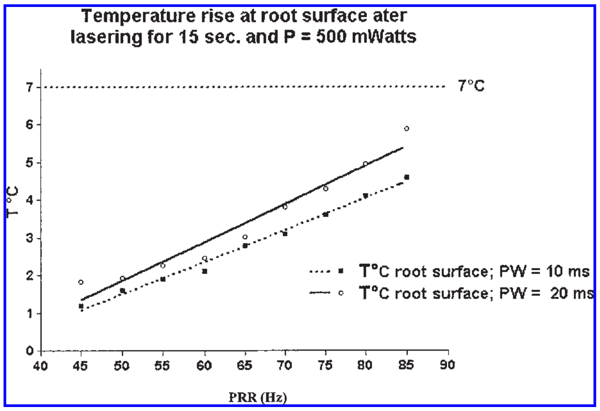

FIG. 4. Linear regression representing the pulpal temperature rise (T°C) in function of the pulse repetition rate (PRR). The temperature rise on the root surface was still below 7°C for an output power of 500 mw, PW ≤ 10 msec; PRR ≤ 30 Hz or for PW ≤ 20 msec and PRR ≤ 20 Hz.

Linear irradiation of 4 mm (four times back and forth) *of root surface for 15 sec with photosensitizer application*

The average of pulpal temperature rise was 1.97°C ± 0.31°C for P ≤ 2 W, PW ≤ 20 msec, and PRR ≤ 20 Hz. For these same conditions, the average temperature rise at the root surface was 2.49 ± 0.23°C. The temperature rise generated by a scanning lasing of one line (4 mm) for 15 sec was always less than the similar lasing on one point.

The temperature rise needed >200 sec before going back to its baseline (Fig. 5). When we rinsed the site of irradiation just at the end of lasing by applying three drops of water (22°C) on the site, we noted that the temperature rise was lower. So, we recommend rinsing the lased site with spray (water-air) immediately after lasing to reduce significantly the temperature rise and wait more than 200 sec before renewed lasing to allow the pulp temperature to go back to its baseline.

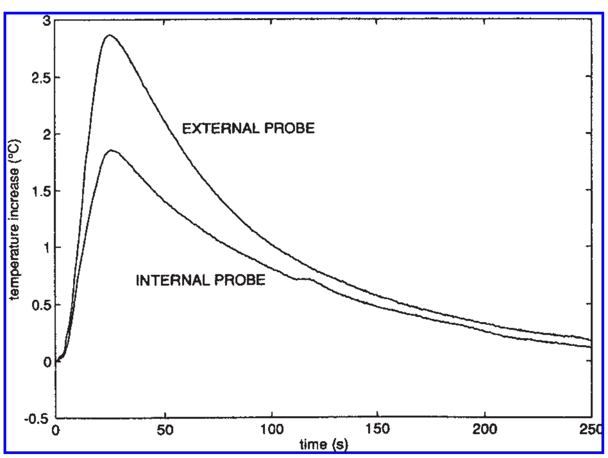

FIG. 5. An example of the temperature increase at the root canal wall (internal probe) and at the external root surface during KTP lasering. The temperature rise needed more than 200 sec before going back to its baseline.

DISCUSSION

The first reports on KTP lasers, from 1986, discussed different applications in medicine. Since that period, several scientific reports were published in the field of dentistry. Different kinds of lasers had a high potential for sterilization of dental tissues (root canal walls and cement)[24,27–34]. The high and selective absorption of KTP beam by Acid Red 52, which is selectively fixed by the caries tissues, seems to be potentially interesting for selective removal of decay without any destruction of the sound dentin. Furthermore, the KTP beam may be used to sterilize the periodontal pocket after the usual, mechanical scaling. In order to verify this sterilization potential, it was necessary to define, in advance, the safety parameters for the pulp and the periodontal tissues. The heat generated by the KTP laser beam during and after lasing in the root canal and on the root surface must stay below the thermal injury threshold for pulp vitality (below 3°C)[38] and for periodontal ligament (below 7°C).[39]

Our results confirmed the irradiation settings for which the KTP laser can be safely used on the root surface without causing harmful temperature effects for pulp vitality and for periodontal ligament in the following conditions:

1. Irradiation on one point of root surface for 15 sec with photosensitizer application; P ≤ 500 mwatts; PW ≤ 10 msec; PRR ≤ 30 or P ≤ 500 mw; PW ≤ 20 msec; PRR ≤ 20 Hz
2. Irradiation of 4 ± 0.2 mm of root surface for 15 sec with photosensitizer application: P ≤ 2 Watts, PW ≤ 20 msec, and PRR ≤ 20 Hz

In our study, we selected an irradiation time of 15 sec in order to simulate clinical situations, allowing enough time to irradiate the site.

We cannot compare our results with others, because our study is the first report in this field of the measurement of pulpal and periodontal temperature increase during KTP lasing of root surface *in vitro*. The absorption of the KTP beam by the components of enamel and dentine is different from other kind of lasers because of the difference in the wavelength of the emission of the KTP laser beam.

This work opens the door for further investigations as far as electron microscopic studies of the root surface after lasing with this wavelength, and for further work to test this laser under controlled conditions for bacteria reduction or sterilization of the root surface. Another investigation could concern root surface access in a true clinical situation, since our work was under ideal laboratory conditions.

In conclusion, the KTP laser may be used safely without thermal damage to pulp and periodontal tissue with respect to the biologically acceptable previously described parameters.[38,39]

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