A Comparative Thermometric Study of Four Semiconductor Laser Devices

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Abstract: A thermometric study was conducted on two experimental (Trial device and Panals 1000; National/Panasonic) and two commercially available (Semilaser Nanox LX-801; G.C. Co. and Trinpl D; Yoshida) semiconductor lasers. This study was carried out in order to verify whether or not these laser types produce any substantial amount of heating during its application on tooth structure. Temperature measurements were done in vitro, using a thermal camera (Thermovision 870; AGEMA) and a thermocouple sensor (Hi-temperature tester). Maximum temperature elevations were recorded during a 60, 120, and 180 second laser exposure. Results showed that factors such as exposure time, power level and operation mode of the laser device, influenced the thermal effects during irradiation. Although the semiconductor laser devices evaluated demonstrated thermal effects, the intrapulpal temperature elevation was not sufficient to cause pulp damage in vivo.

1. Introduction

Low-energy laser therapy, despite of present controversies on its effectiveness and the lack of concrete evidences and results on controlled groups, still continues its development and popularity because of its low irradiation intensities and harmless biologic effects.1-3) Investigations on low-energy laser therapy have been going on since the late sixties and much credit has been given on biologic effects such as increased pain tolerance, immunostimulation, vasodilation leading to increased metabolism, earlier resolution of edema, accelerated intracellular metabolism, and overall stimulation of wound healing.2-4)

In the field of dentistry, soft lasers are most commonly advocated for the treatment of hypersensitive dentin,4-8) gingivitis, pulp-capped teeth, herpes labialis, alveolitis, oral ulceration10-15) periodontal disease,16) pericoronitis, pulpitis, nausea caused by dental procedures, and in the promotion of healing of extraction sites.3) Although several theories have been presented to explain the effectiveness of low-laser energy, a widely accepted mechanism of action has yet to be isolated. It is said however that its power is so low that any effect caused by these types are due to direct effects of the radiation and not as the result of heating.1,3)

The most commonly used device in low-energy laser therapy is the He-Ne laser. The recent availability of semiconductor diode lasers however, has focused great attention on its application in the medical and dental field. The wavelength of these lasers depends on the composition of the semiconductor; GaAlAs emits wavelengths between 750 nm and 905 nm.3)

This investigation is a comparative thermometric study of two experimental (Trial device and Panals 1000; National/Panasonic) and two commercially available (Semilaser Nanox LX-801; G.C. Co. and Trinpl D; Yoshida) semiconductor lasers. This study was conducted in order to verify whether or not these laser types produce any substantial amount of heating during its application on tooth structure.

2. Materials and Methods

An extracted central incisor was selected for
this study. For measurements of thermal changes in the pulp chamber, readings on the electronic digital thermometer (Hi-Temperature Tester; Japan) were recorded. An opening, approximately 1 mm, through the lingual surface of the specimen was made into the pulp chamber. A thermocouple (K-type Cr/Al) connected to a digital thermometer was then inserted to approximate the cervical third on the labial surface, the site of laser irradiation. Radiographs were taken to confirm the position of the heat sensor.

For measurements of thermal changes on the surface of enamel, an infrared thermal camera (Thermovision 870 System), was used. During thermography, computer recordings were done on a 10 second interval of laser irradiation.

The specimen was firmly affixed by the placement of an orthodontic wire in an opening made through the apex, which was also reinforced by self cure resin. The wire was then positioned permanently on a stand allowing the exposure of the cervical third of the tooth in direct contact with the laser tip. The laser tip was also positioned on the same stand for its easy control.

Four semiconductor laser devices were evaluated in this study. Temperature measurements for all devices were taken before and after laser irradiation, and during a 60, 120, and 180 second laser irradiation.

3. Results

Figure 1 presents the graph of the mean values of the temperature rise during thermographic measurements of laser irradiation of the four types of semiconductor lasers used in this study. Thermographic results show that Panals 1000 in a continuous wave mode approached almost 5°C temperature rise, while Tripl D produced the least increase in temperature. Temperature readings of the thermal changes inside the pulp were recorded unremarkable for Tripl D, and Semilaser Nanox LX-801, Trial device (20mW), and Panals 1000 (25% 1, 2, 4 Hz). No temperature change was observed for these devices. Panals 1000 in a continuous wave mode also presented the highest intrapulpal temperature elevation of 3°C. The temperature elevation on enamel steadily increased to peak value after 120 seconds. Temperature elevations for pulp chamber warming were also steady and likewise reached a peak value after 120 seconds.

4. Discussion

Soft lasers as defined, are low-power devices which emit in the visible or near infrared region of the spectrum, and whose power is too low to have any thermal consequences.1,2) It is said therefore that any effects caused by these types of lasers are due to direct effects of radiation and not as the result of heating.1) It has been said that temperature elevations of soft lasers should be minimal and should not exceed 0.1-0.5°C. This would limit the laser powers to only about 50 mW or energies of only a few joules/cm².1) Of the four laser devices evaluated, only Tripl D was observed to comply with the aforementioned restrictions. The other laser devices exhibited a temperature elevation on the enamel surface greater than 0.5°C.

As we know, dental tissues are affected by elevation of temperature. In this study, temperature elevation on enamel surface was observed to range from as low as 0.5°C to as high as 4.8°C. Kramer demonstrated that even when the enamel temperature increases substantially, this heat may not necessarily be transferred to the pulp and cause damage since dentin is a good insulator and a poor conductor of heat.14) The classic study by Zach and Cohen also showed that an intrapulpal temperature rise as small as 5.5°C was sufficient to cause the loss of vitality in several teeth.15) However, the highest recorded intrapulpal temperature rise in this study...
was only 3°C. It seems that heat, although transmitted into the pulp chamber, was very minimal. That the four semiconductor lasers which were evaluated, resulted in a very low intrapulpal temperature rise signifies a relatively high safety level for their direct use on enamel.

The thermal elevations monitored in this study were observed to depend on such factors as exposure time, power level, operation mode, and even the model of the laser device used. Temperature elevation was in direct ratio to the applied power and exposure time of laser radiation. As was seen in this study, a 180 second exposure time using low power levels resulted in unremarkable thermal consequences. The laser devices in this group include Trinpl D, Nanox 801, Trial device (20-40 mW), and Panals 1000 25% (1-4 Hz). These results suggest that these lasers are not only quite safe for a 180 second exposure but may even be used for longer and repetitive periods of irradiation.

Another factor observed to have some influence over the thermal changes monitored in this study is the model of the laser device used. Interestingly, the 60 mW trial device (CW) by National/Panasonic resulted in 3°C temperature change on enamel and only a 1°C temperature rise intrapulpally during a 180 second laser exposure. Compared with the other trial device by the same company, the 60 mW Panals 1000 (CW), resulted in a higher temperature elevation on enamel and in the pulp. Hence, the possibility that variations exist in the actual output of laser energy within the same manufacturers and between other manufacturers should not be overlooked.

Fig. 2. Both are thermographic results of panals 1000. As seen here (B), the heat build-up using the continuous wave mode was greater than the pulse 75% 8 Hz mode (A).
Although no report to date has been published using the same type of trial devices, similar semiconductor diode laser devices have been documented effective in a wide range of clinical application at the same time producing no pathohistologic findings. Based on the results of this thermometric study, we have reason to believe that the four semiconductor devices studied may be safely used clinically for a 180 second laser irradiation. The thermometric results have no bearing on the effectiveness of the individual lasers in clinical practice. Moreover, it is not within the scope of this paper to critically evaluate the effectiveness and benefits of these semiconductor lasers. Finally, one must exercise caution in assessing results of an in vitro experiment. Temperature measurement devices are susceptible to errors, and also do not measure biologic reactions. The actual thermal damage to the pulp or odontoblasts would best be assessed by a well designed histologic study. However, great efforts were exerted to minimize variables which could have affected the rate of thermal conduction through dentin during this thermometric study.

5. Conclusion

The temperature rise on the external and internal surface of a central incisor was measured in an in vitro investigation during the irradiation of four different GaAlAs semiconductor laser devices. The results suggested that the amount of heat conducted to the pulp chamber during irradiation may be insufficient to cause thermal damage. The direct laser irradiation on enamel for a period of three minutes can be regarded as safe.

References


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