10.5005/jp-journals-10024-1933

ORIGINAL RESEARCH

450 nm Blue Laser and Oral Surgery: Preliminary *ex vivo* Study

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ABSTRACT

Introduction: Dental diode lasers were started to be used at the end of the 1990s and were shown to possess several important characteristics, such as small size and low cost, as well as the advantage of optic fibers delivering system. Although only two wavelengths (810 and 980 nm) had been the most used dental diode lasers, a wavelength emitting in the blue portion of the spectrum has recently been proposed.

Aim: The aim of this *ex vivo* study was to compare the effectiveness of five different fiber-delivered laser wavelengths (450, 532, 808, 1064, and 1340 nm) in the oral soft tissue ablation.

Materials and methods: Specimens were surgically collected from the dorsal surface of four bovine tongues and, while deep thermal increase was measured by two thermocouples at 0.5 and 2 mm depth, surface temperature was recorded by an infrared thermometer. Subsequently, specimens were fixed in 10% buffered formalin solution, cut into slices, and embedded in paraffin blocks, and a pathologist made a morphological analysis by optic microscope assigning a score based on the quality of the cut and tissue damage.

Results: The analysis showed the best quality of the cut and the lowest temperature increase on the specimens obtained with the shortest laser wavelength (450 nm).

Conclusion: Even considering this as preliminary study, the use of 450 nm blue diode laser in oral surgery may be suggested to the clinician in their daily practice.

Clinical significance: This study opens a new perspective in oral surgery. Blue diode laser has demonstrated a good quality of the cut with a low energy causing a minimal thermal damage to the tissue, promising a better comfort to patients.

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Keywords: 450 nm, Diode, *Ex vivo*, Laser, Optic fiber, Oral surgery, Thermocouple.

How to cite this article: Fornaini C, Merigo E, Rocca J-P, Lagori G, Raybaud H, Selleri S, Cucinotta A. 450 nm Blue Laser and Oral Surgery: Preliminary *ex vivo* Study. J Contemp Dent Pract 2016;17(10):795-800.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Goldman[1] described the first clinical purpose of laser technology in dentistry in 1964, 4 years after the construction of the first laser device (ruby laser) by Maiman in 1960, and the reasons for this delay may be explained by the difficulty in delivering the laser beam into a small cavity, such as the mouth (the solution for this problem was found only by the realization of efficient delivery systems, such as optic fibers), and by the need to utilize at least two different wavelengths, the first for hard tissues and the second for soft tissues, both present inside the mouth.

Moreover, during irradiation, thermal elevation must remain under the values compatible with the biological integrity of the tissues, and this is the reason why we may mention the first studies by Goldman, Kinersly, Morrant, Stern, and Taylor[1-5] just for their historical relevance, and we consider the paper by Frame[6] in 1984 as the first description of an *in vivo* oral surgical intervention using a CO_2 laser ($\lambda = 10{,}600$ nm) without biological damages on tissues.

The advantages of laser surgery include reduction of the operating time, the possibility to cut and coagulate at the same time, a better vision of the operating field, avoiding the use of the sutures, the decrease in pain, sometimes without the need of anesthetic injections, the disinfection of the operating field, and a better and faster healing process (biostimulating effects) in order to avoid the assumption of drugs with a good comfort in the immediate follow-up.[7-10]

Beyond CO_2, neodymium-doped yttrium aluminum garnet (Nd:YAG; $\lambda = 1064$ nm) laser has also been used, the first pulsed and fiber-delivered laser as well as diode ($\lambda = 810$ and 980 nm)[11]; furthermore, neodymium-doped yttrium aluminum perovskite (Nd:YAP) laser ($\lambda = 1340$ nm), due to its absorption by water, has been found to play a greater role in oral surgery.[12]

In 1989, Keller and Hibst[13] proposed the use of erbium-doped YAG laser for cavities prepared in conservative dentistry.

This wavelength (2,940 nm), being highly absorbed by water (3,000 nm) and hydroxyapatite (2,800 nm) included in a large percentage into the hard oral tissues, causes the cells to burst, destroying the target tissue.[14]

The first dental laser emitting in the visible light was argon, a solid state laser emitting at 435 nm, which found its main utilization in conservative dentistry, specifically to polymerize composite resins thanks to the high absorption by camphorquinone, but also used for oral surgery.[15] Unfortunately, it was discontinued due to the great dimension and high cost.

Conversely, potassium titanyl phosphate (KTP) laser ($\lambda = 532$ nm), recently accepted as a good device for oral surgery, allows to diminish the energy maintaining a high cut quality;[16] the only difficulty for the operator is related to the brightness of its green beam, solved by the mandatory use of protective gloves.

An original recent study conducted by a supercontinuum source and regarding the transmission of different wavelengths in different animal tissues[17]puts the laser–tissue interactions in a new perspective.

It effectively demonstrated that the lowest transmission is present in two windows, the first in the visible portion, particularly in blue and green, and the second in the far infrared (IR) between 1,300 and 1,700 nm, suggesting the surgical use of the blue laser, and also considering the aspects described below.

Enwemeka[18] demonstrated its antimicrobial power and proposed it as an alternative to antibiotics; moreover, its effect on the inhibition of methicillin-resistant *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* and its effect on the growth of periodontal biofilm were described in many *in vitro* studies.[19-21]

An *in vitro* photodynamic therapy work[22] compared three visible laser wavelengths coupled to three different chromophores on *Streptococcus mutans* cultures: 405 diode laser coupled to curcumin obtained, in terms of growth inhibition, results that ranged between 70.96% (Fluence of 10 J/cm^2) and 99.10% (Fluence of 30 J/cm^2).

Also in low-level laser therapy (LLLT), which Smith redefined as low-level light therapy by including also the light-emitting diode (LED) lamps,[23] the blue light seems to play an important role. Adamskaya[24] demonstrated the efficacy of LED for a faster wound healing by *in vivo* rat model, while Kushibiki[25] showed, after blue laser irradiation, intracellular modifications.

Thus, based on these biomodulating properties, the use of blue light started to be largely used for several skin treatments, such as acne and rejuvenation.[26]

As described earlier, the first indication for the use of blue laser in dentistry was the composite resin polymerization; in fact, while the studies performed by argon laser demonstrated its efficacy, results obtained by diode laser seem to be not encouraging.[27-31]

Blue diode laser has recently been proposed, coupled to titanium oxide, for dental bleaching.[32]

The aim of this *ex vivo* work was to analyze the effectiveness of five different fiber-delivered laser wavelengths (450, 532, 808, 1064, and 1340 nm) in oral surgery on animal models by recording surface and deep temperatures, speed of cut, and histological changes.

MATERIALS AND METHODS

Sample Collection

Two fresh beef tongue were kept at 2 to 4°C and 100% humidity until the test; the experiments were performed at room temperature (22–24°C).

Two samples of 15 × 10 mm dimension and 4 mm thickness were obtained from the ventral portion of each tongue (Fig. 1) and were put in a special device (Mini DIY Desktop Laser Engraving Printer Cutting Machine, modified) which permits to use different laser handpieces perfectly controlling shape, dimension, and

Fig. 1: Samples utilized in the study

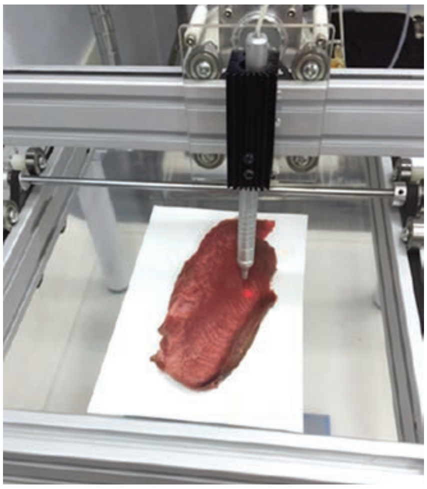


Fig. 2: The device used to control the speed of irradiation

Fig. 3: Sample obtained after the irradiation, the holes are the site where thermocouples were positioned

speed of the ablation avoiding the variability related to operator skill (Fig. 2).

In each wavelength, a linear cut of 5 cm, at a speed of 5 mm/sec, was performed (Fig. 3), and two k-thermocouples were inserted at 1 mm from the edge of the cut, in the middle of the line, the first at a depth of 0.5 mm and the second at a depth of 2 mm.

Surgical Devices

The laser devices employed and the parameters used were those described below (Figs 4A to E); all the appliances were used with the same 320 µm optic fiber, previously checked by a Power-meter (Thorlabs PM 100, Germany).

- Hermes Blue diode (Gardalaser, Italy) λ = 450 nm, 2 W CW (Fig. 4A)
- LASEmaR KTP500 (Eufoton, Italy) λ = 532 nm, 2 W CW (Fig. 4B)
- LASEmaR diode 800 (Eufoton, Italy) λ = 808 nm, 3 W CW (Fig. 4C)
- LightWalker Nd:YAG (Fotona, Slovenia) λ = 1,064 nm, 3 W, 30 Hz (Fig. 4D)
- Lokki Nd:YAP (Lobel Medical, France) λ = 1,340 nm 5 W, 160 mJ (Fig. 4E).

Figs 4A to E: Lasers used: (A) LASEmaR 500; (B) LASEmaR 800; (C) Ermes laser; (D) LightWalker; and (E) Lokki

Measurement of Variation of Temperature

In-depth Temperature

The in-depth variation of temperature was recorded by two naked-bead chrome aluminum (K-type) thermocouples (TP-01, Lutron, Taiwan) with a 0.5-mm diameter probe sensitive to temperature variations between –40°C and 250°C; the thermocouples were connected to a two-channel thermometer (TM-946, Lutron, Taiwan) sensitive to temperature variations (for k-type thermocouples) between −100°C and 1,300°C, with an accuracy of 0.1°C.

Surface Temperature

The superficial variation of temperature was measured by an IR thermometer (ScanTemp, Dostmann, Germany); it was recorded before starting surgical procedure and before the complete excision of the sample to evaluate the thermal elevation during the surgical process.

Excision Time

Operative time of each surgical procedure was considered from the start of laser application on tissue until the complete ablation on all the sample thickness.

Histological Evaluation

The specimens were fixed in a 10% buffered formalin solution, cut into slices, and embedded in paraffin blocks, according to conventional methods; subsequently, sections of 5 µm thickness were obtained for hematoxylin and eosin staining.

These sections were then observed under low- and high-power light microscopy (Olympus MTV-3, Japan) by a pathologist unaware of the used wavelength: The pathologist assigned to each incision a cut quality score (0–5), "5" representing the highest (cold blade).

RESULTS

Excision Time

The time necessary to cut the samples was 215 seconds (1,340 nm), 264 seconds (450 nm), 270 seconds (532 nm), 275 seconds (1,064 nm), and 292 seconds (808 nm) (Graph 1).

Superficial Temperature

The increase in surface temperature, measured by the IR thermometer, gave the following values of ΔT (difference between the final and initial temperatures): 22.7°C for 1,340 nm, 16.7°C for 1,064 nm, 15.2°C for 808, 11.1°C for 532 nm, and 8.8°C for 450 nm (Graph 2).

Deep Temperature

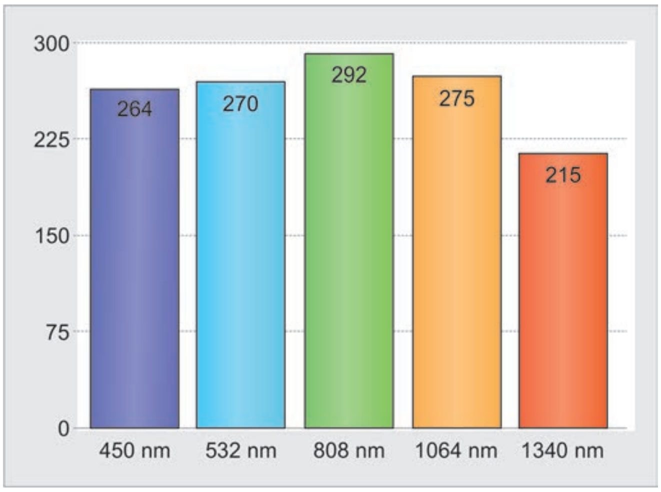
The increase in in-depth temperature, measured by the two thermocouples, gave the following values of ΔT (difference between the final and initial temperatures): 26.5°C for 1,340 nm, 22.6°C for 1,064 nm, 16.9°C for 808, 13.1°C for 532 nm, and 11.6°C for 450 nm (Graph 3).

Quality of Incision

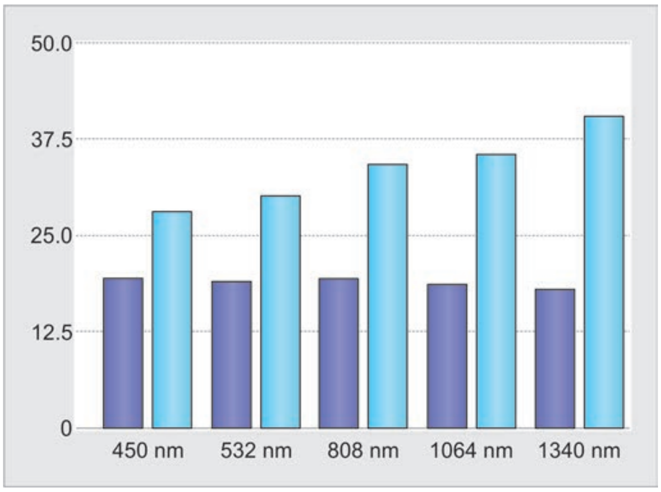
The scores on the quality of incision assigned by the pathologist were 3 for 450 and 532 nm, 2 for 808 nm, and 1 for 1,064 and 1,340 nm, as shown in Graph 4.

DISCUSSION

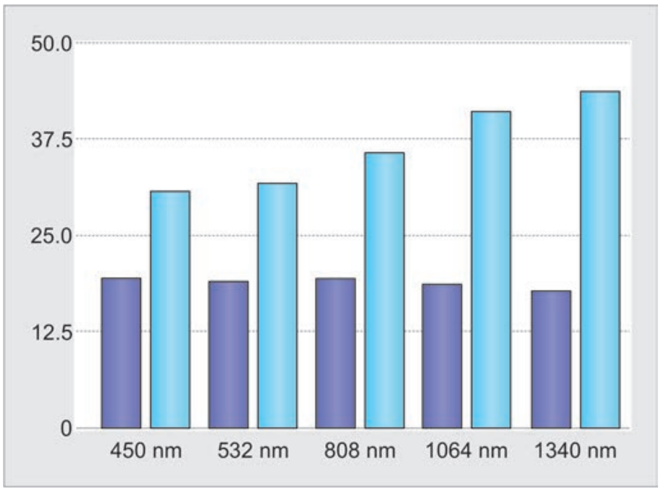
In 1962, four US groups (General Electric Research Centre, IBM Watson Research Centre, MIT Lincoln Laboratory, and RCA Laboratories) constructed the first diode laser based on semiconductor active medium; these kinds of laser were also realized in the USSR in early 1963 by the Nikolaj Basov team.[33-35]



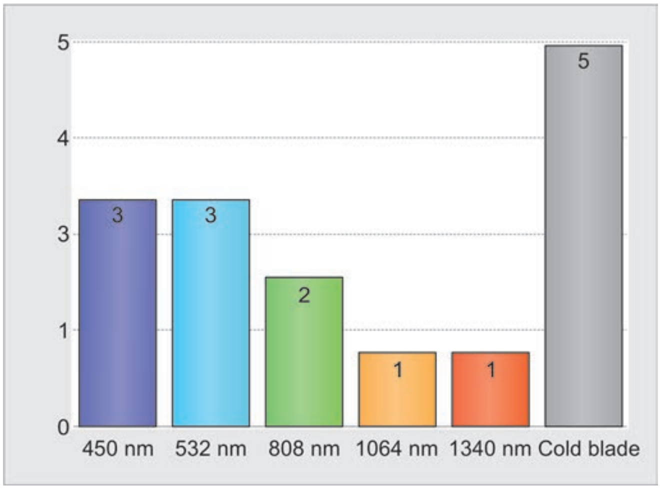
Graph 1: Comparison of the times necessary to perform the excision



Graph 2: Comparison of surface temperature increases



Graph 3: Comparison of deep temperature increases



Graph 4: Incision quality scores assigned by a pathologist

Diode lasers were largely also employed in dentistry thanks to their reduced size and price and also for the large numbers of utilization, such as soft tissue surgery,[36] orthodontics,[37] endodontics,[38] periodontics,[39] bleaching,[40] and LLLT.[41]

Up to date, two wavelengths are used in dentistry, 810 and 980 nm, emitting in the near IR portion of the spectrum: In fact, thanks to their good absorption in hemoglobin, they have a good bleeding control during surgical interventions.

Conversely, the use of visible lasers in dentistry was not popular and the reasons were represented by the necessity to employ necessity to employ solid and gaseous active media appliances with high cost and great sizes. The only studies reported in the literature are limited to argon and KTP lasers.[15,16]

When diode laser devices emitting in the blue were introduced, the dental market acquired a new possibility. This study is the first to compare the traditional wavelengths used in oral surgery to blue diode laser.

The thermal effects of lasers on biological tissues generally result from three different phenomena: The light conversion to heat, the heat transfer to the tissue, which includes the temperature and the exposure time, and the consequent protein denaturation and tissue vaporization. The laser effects depend on the parameters used (wavelength, power, time and mode of emission, beam profile, and spot size) and also on the optic and chemical characteristics of the target tissue. Hyperthermia, consisting of a moderate rise in temperature (41–44°C for some tens of minutes), results in cell death while coagulation, irreversible necrosis without immediate tissue destruction, occurs at temperatures around 50 to 100°C for 1 second at least, producing desiccation, blanching, and shrinking of tissues due to the denaturation of proteins and collagen. Volatilization, above 100°C, induces tissue transformation into smoke in a very short time (one tenth of a second) and forms a region of coagulative necrosis at the edges of the volatilization zone.[42]

This study, although performed only on a limited number of samples, may be considered useful to the clinician for evaluating the advantages offered by 405 nm diode laser in oral surgery.

The fastest incision was obtained by the Nd:YAP laser at 5 W, while the slowest was given by the diode 808 nm at 3 W, and it may be explained based on the great absorption of 1,370 nm wavelength by water. However, we must also consider that the *ex vivo* model used here is less hydrated than the *in vivo* model, so obtaining a faster effect when used on patients.

Regarding the superficial temperature, measured through the IR thermometer, the highest difference between the initial and final temperatures (ΔT) was observed with the use of 1,340 nm laser at 5 W of power, while the lowest was recorded with the 450 nm wavelength at 2 W. The temperature increasing in the deepest tissues, measured through the use of thermocouples, was the highest with the use of 1,370 nm wavelength at 5 W, while the lowest was recorded with the use of 450 nm wavelength at 2 W.

CONCLUSION

Even if this study must be considered as preliminary due to the limited number of samples and also by the limits related to the differences between the *ex vivo* and *in vivo* models, it opens a new perspective on the oral soft tissue laser surgery, proposing the utilization of blue diode laser, which demonstrated a good cut performance without causing high thermal elevation with respect to the tissues.

CLINICAL SIGNIFICANCE

By hypothetically transferring these results to the treatment of patients, the use of blue diode laser is very interesting, suggesting its utilization to the clinicians. Even if further *in vivo* studies are necessary to confirm these results, we may suppose a better and faster healing process with greater comfort for the patients themselves.

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