Blue diode laser: a new approach in oral surgery?

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ABSTRACT

The introduction of diode lasers in dentistry had several advantages, principally consisting on the reduced size, reduced cost and possibility to beam delivering by optical fibbers. Up today two diode wavelengths, 810 and 980 nm, were the most utilized in oral surgery but recently a new wavelength emitting in the blue had been proposed.
The aim of this *ex vivo* study was to compare the efficacy of five laser wavelengths (450, 532, 808, 1064 and 1340 nm) for the ablation of soft tissues.
Specimens were surgically collected from the dorsal surface of four bovine tongues and irradiated by the five different wavelengths.
Thermal increase was measured by two thermocouples, the first at a depth of 0.5 mm, and the second at a depth of 2 mm while initial and final surface temperatures were recorded by IR thermometer.
The quality of the incision was histologically evaluated by a pathologist by giving a score from 0 to 5.
The time necessary to perform the excision varied between 215 seconds (1340 nm, 5W) and 292 seconds (808 nm, 3W).
Surface temperature increase was highest for 1340 nm, 5W and lowest for 405 nm, 4 W. The most significant deep temperature increase was recorded by 1340 nm, 5 W and the lowest by 450 nm, 2 W.
The quality of incision was better and the thermal elevation lower in the specimens obtained with shortest laser wavelength (450 nm).

INTRODUCTION

The first application of laser technology in dentistry was described by Goldman in 1964, four years after the realization of the first laser device, the "Ruby Laser", by Maiman in 1960[1].
The main reasons of this delay are, on the one hand the difficulty of the beam delivering in a small cavity such the mouth which was solved only by the finalizing of efficient delivery systems and, on the other hand the necessity to utilize different wavelengths due to the different target tissues present into the oral cavity.
Another problem found by the first researchers who used laser technology in oral applications was the need of limit thermal elevation under values compatible with the biological integrity of the tissues.
For this last reason the first studies, including those by Goldman, Kinersly, Morrant, Stern and Taylor may be considered only for their historical relevance[2-5] by considering the paper by Frame in 1988 as the first which described an "in vivo" oral surgery intervention using a CO_2 laser (λ =10600 nm) without collateral biological damages[6].
The advantages of soft tissues laser surgery consist in a reduction of the operating time, the possibility to combine the cut with the coagulation of the target tissue, so giving a better vision of the operating field as well the possibility to avoid the use of the sutures, , the reduction of the pain, sometimes eliminating the necessity of anesthetics injection, the disinfection of the field and, thanks to the biostimulating effects, a better and faster healing process, so avoiding the utilisation of drugs and having a good comfort in the post-operating time[7-10].
In addition to CO_2, were employed also Nd:YAG (λ =1064 nm), the first laser pulsed fibber-delivered, and lastly the diodes (λ =810 and 980 nm), with a strong reduction of size and cost[11]; also Nd:YAP laser (λ =1340 nm), due to its good affinity for the water, found a great role in the oral soft tissue surgery[12].

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In 1990 Hibst and Keller originated a real revolution in dentistry by proposing the possibility to use Er:YAG laser for cavities preparing in conservative dentistry[13].

This wavelength (2940 nm) being very close to the absorption peaks of the water (3000 nm) and hydroxiapatite (2800 nm), largely present in the oral tissues, causes the explosion of the intracellular water and so the destruction of the target[14].

As we can see, the wavelengths used in oral surgery were all limited to the infrared portion of the spectrum.

The first exception to this choice was represented by the utilization of Argon laser, a solid state laser emitting at 435 nm, which found its applications in the restorative dental field, specifically to polymerize composite resins due to its affinity for camphoroquinone, and also in oral surgery[15] but its use was soon abandoned due to its great dimension and high cost.

On the contrary, KTP laser (λ =532 nm) was recently described as a good device for oral surgery, its utilization allowing to reduce the energy delivered with a very effective cut quality[16]; the only problem is related to the great brightness of its green beam even if the special protective gloves may solve this inconvenient.

A recent study on the transmission of different wavelengths in different tissues performed trough the utilization of a supercontinuum source[17] allowed to consider the laser-tissue interactions, in particular the transmission, in a new perspective.

In fact, this work indicated the lowest transmission in two windows, the first in the visible portion, in particular blue and green, and the second in the far infrared, for wavelengths between 1300 and 1700 nm, adding so one reason more for suggesting the use of the blue laser in dentistry.

The antimicrobial power of the blue light was demonstrated by Enwemeka who proposed it as an alternative to the antibiotics[18], and its high inhibitory effect on methicillin-resistant *Staphylococcus Aureus*, *Escherichia Coli* and *Pseudomonas Aeruginosa*, as well as its effect on periodontal biofilm growth was showed in several *in vitro* studies[19-21].

Another *in vitro* experimental work in the field of Photodynamic Therapy[22] compared three visible laser wavelengths coupled to three different chromophores on *Streptococcus Mutans* cultures and the 405 diode laser in association with Curcumine curcumin obtained results in terms of growth inhibition variable between 70,96% (Fluence of 10 J/cm2) and 99,10% (Fluence of 30 J/cm2).

Also in the field of LLLT, which Smith re-defined as “Low Level Light Therapy” by including also the use of LED lamps[23], the blue light has been demonstrated to have an interesting and effective power: while Adamskaya described the blue LED efficay in wound healing improving, using *in vivo* rats model[24], Kushibiki showed the intra-cellular modification after blue laser irradiation[25].

On the basis of these biomodulating properties, the use of blue light is largely used for several skin treatments, from acne to rejuvination[26].

One of the first indications for the employ of the blue laser in dentistry consisted, as above described, on the composite resin polymerization even if the literature is discordant: while in the studies performed by argon laser demonstrate its efficacy, the works by diode laser are not encouraging[27-31].

Recently, blue diode laser has been proposed also for dental bleaching, in association with titanium oxide[32], while at the moment it doesn’t yet exists any work in literature about the use of the blue diode laser in oral surgery.

The aim of this *ex vivo* work was to compare the performance of six different laser wavelengths (450, 532, 808, 1064 and 1340 nm) in oral soft tissues surgery, on animal models trough the recording of the surface and deep thermal increase, the speed of cut and by histological modifications evaluated by two blind pathologists.

MATERIALS AND METHODS

Samples collection

Two fresh beef tongues were used to perform this study; they were conserved at the temperature of 2-4° C and 100% of humidity during the transit to prevent tissue degradation and all measurements were made at room temperature, about 22-24° C. (Figure 1)

Figure 1: The two tongues used in the study.

From the ventral portion of each tongue, two samples of 15 x 10 mm dimension and 4 mm of thickness were obtained. (fig. 2)

Figure 2: The samples used in the study.

To avoid the variability related to the operator ability, each sample was located in a special appliance (Mini DIY Desktop Laser Engraving Printer Cutting Machine, modified) which allows to insert different laser handpieces and to perfectly control the shape and dimension of the ablation: it was chosen to perform a linear cut of 5 cm, at a speed of 5 mm/sec for each wavelength used (Figure 3).

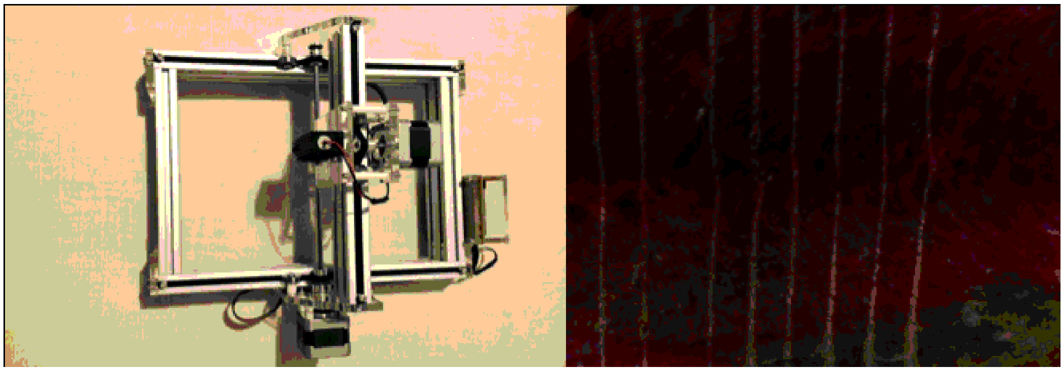

Figure 3: The device used and one of the samples obtained after the irradiation.

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

In this study the following medical devices were used:

a) Ermes Blue diode (Gardalaser, Italy) λ = 450 nm, 2 W CW (fig.4/a)
b) LaseMar KTP 500 (Eufoton, Italy) λ = 532 nm, 2 W CW (fig.4/b)
c) LaseMar diode 800 (Eufoton, Italy) λ = 808 nm, 3 W CW (fig.4/c)
d) LightWalker Nd:YAG (Fotona, Slovenia) λ = 1064 nm, 3W, 30 Hz (fig. 5/a)
e) Lokki Nd:YAP (Lobel Medical, France) λ = 1340 nm 5W, 160 mJ (fig.5/b)

Fig. 4: Ermes laser (left), LaseMar 500 (center), LaseMar 800 (right)

Fig. 5: LightWalker (left), Lokki (right)

All the devices were used with the same 320 µm optical fibber that, before the test, had been checked by a Power-meter (Thorlabs PM 100- Germany).

Measurement of variation of temperature

A) In-depth temperature

In order to evaluate the in-depth variations of temperature, two naked-bead chrome aluminium (K-type) thermocouples (TP-01, Lutron, Taiwan) with a 0.5-mm diameter probe sensitive to temperature variations between −40°C and 250°C

were placed; 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 1300°C, with an accuracy of 0.1°C.
B) Surface temperature
In order to evaluate surface variation of temperature, an InfraRED (IR) thermometer (ScanTemp, Dostmann, Germany) was used. The surface temperature of the sample was recorded before starting surgical procedure and before complete excision of the sample, to compare the thermal elevation during the surgical process.
Time of excision
Operative time about each surgical procedure was considered since laser application on tissue until when the ablation was performed on all the thickness of sample.
Histological evaluation
The specimens were fixed in a 10% buffered formalin solution, cut into slices, and embedded in paraffin blocks, according to conventional methods.
Sections of 5 μm thickness were obtained for haematoxylin and eosin staining.
The histo-pathological sections were evaluated under low- and high-power light microscopy (Olympus MTV-3, Japan) by a pathologist unaware of the used wavelength.
A cut quality score (Ranging 0-5) was assigned to each incision, score "5" representing the highest quality (cold blade).

RESULTS

Excision time
The time necessary to perform the excision varied between 215 seconds (1340 nm, 5W) and 292 seconds (808 nm, 3W) (Table 1)

Laser	Time (sec)
450 nm	264
532 nm	270
808 nm	292
1064 nm	275
1340 nm	215

Table 1: Time necessary to perform the excision.

Superficial temperature increasing.
Surface temperature increasing was highest for 1340 nm at 5W (22.7) and lowest for 450 nm at 2W (8.8) (Table 2).

Laser	Initial temperature (°C)	Final temperature (°C)
450 nm	20.1	28.9
532 nm	19.9	31.0
808 nm	20.0	35.2
1064 nm	19.6	36.3
1340 nm	18.6	41.3

Table 2: Surface temperature increase.
Deep temperature
The most significant temperature increasing was observed with 1340 nm at 5 W (26.5) and the lowest with 450 nm at 2 W (11.6).The highest peak power was reached by 1340 nm laser (46.9) and the lowest by 450 nm laser (33.9).
The results are shown in Tab.3

Laser	Initial temperature (°C)	Final temperature (°C)
450 nm	20.1	31.7
532 nm	19.9	33.0
808 nm	20.0	36.9
1064 nm	19.6	42.2
1340 nm	18.6	45.1

Table 3: Deep temperature increase.

Quality of incision.

The pathologist assigned the best score about the quality of incision (3/5) to the lasers emitting in the visible portion of the spectrum (450 and 532 nm), as shown in the Tab. 4.

Laser	Score
450 nm	3
532 nm	3
808 nm	2
1064 nm	1
1340 nm	1
Cold blade	5

Table 4: Incision quality score assigned by pathologist

DISCUSSION

The first diode laser, that is the coherent light emission from a gallium semiconductor, was demonstrated in 1962 by two US groups led by Robert N. Hall at the General Electric Research Centre[33] and by Marshall Nathan at the IBM T.J. Watson Research Centre[34].

Other teams at MIT Lincoln Laboratory, Texas Instruments, and RCA Laboratories were also involved in and received credit for their historic initial demonstrations of efficient light emission and lasing in semiconductor diodes in 1962 and thereafter; GaAs lasers were also produced in early 1963 in the Soviet Union by the team led by Nikolay Basov[35].

Diode lasers had soon a great diffusion in dentistry thanks to their advantages, when compared to the solid state lasers, such reduced size and price, optical fibber delivery system and possibility to be used in a large number of dental applications such soft tissues surgery[36], orthodontics[37], endodontics[38], periodontics[39], bleaching[40] and LLLT[41].

The two wavelengths up to day mainly used in dentistry are 810 nm and 980 nm, emitting in the near infrared portion of the spectrum, the reason of this choice by the producers probably consisting in the good absorption in haemoglobine with result of giving a good bleeding control which is a great advantage in surgical procedures.

Regarding the use in dentistry of laser wavelengths ranging in the visible portion of the spectrum, the limit was represented by the necessity to employ solid state appliances, with high costs and great size and so the only studies reported in literature are limited to Argon and KTP lasers[15, 16].

With the introduction in the dental market of diode laser devices emitting in the blue, new perspectives were opened and this is the first study comparing, by point of view of the thermal effects, the traditional wavelengths to this new laser in oral surgery.

The thermal effects of lasers on biological tissue result from three phenomena: conversion of light to heat, transfer of heat and the tissue reaction, which is related to the temperature, and the time of exposure; the interaction of these factors leads to denaturation or to tissue destruction. The laser effects depend on the parameters used (wavelength, power, time and mode of emission, beam profile, and spot size) altogether with the chemical and physical characteristics of the target tissue. Hyperthermia consists of a moderate rise in temperature, ranging from 41 to 44°, for some tens of minutes and resulting in cell death due to changes of enzymatic processes. Coagulation is an irreversible necrosis without immediate tissue destruction. The temperature reached (50–100°C) for around 1 s, produces desiccation, blanching, and a shrinking of tissues by denaturation of proteins and collagen. Volatilization induces tissue transformation into smoke at above 100°C in a relatively short time of around one tenth of a second. At the edges of the volatilization zone there is a region of coagulative necrosis. There is a gradual transition between the volatilization and healthy zones[41].

Even if the present observational study, on the basis of its preliminary nature, was performed only on a limited number of samples, therefore, it may be useful to the clinician for evaluating the advantages offered by 405 diode laser in the surgery of oral soft tissues.

In this work, the quickest incision was obtained through the use of the Nd:YAP laser with a power of 5 W while the slowest was performed through the 808 nm used at 3 W and, as described before this may be explained on the basis of the highest affinity of 1370 nm wavelength for water. However, we should take in consideration that the “ex vivo” model here used may well be less hydrated than the “in vivo” model thus leading to an even faster incision when this laser is used on a patient. As expected, the lowest wavelength has also the slower speed of cut, this showing that, in the infrared portion of the spectrum, the rapidity of incision is related to the increasing of wavelength.

Regarding to the superficial temperature, measured through the IR thermometer, the highest difference between the initial temperature and final temperature (ΔT) was observed during the use of 1340 nm laser at 5W of power while the lowest was recorded with the 450 nm wavelength at 2W. The temperature increasing in the deepest tissues, measured through the use of thermocouples, was the highest with the use of 1370 nm wavelength at 5W while the lower was recorded through the use of 450 at 2W.

Hypotetically transferring these results to the patient treatments, they seem to be very interesting suggesting a better and fasting healing process with greater comfort for the patients themselves.

CONCLUSION

Three parameters are important for the evaluation of new technologies in oral surgery[43]: patient compliance during pre- and post-operative phases[44], comfort of the surgeon and possible histological damages. The possible problems of such a tool are the inflammation in the incisional area, the control of thermal modifications, and the quality of excised tissues[45]: when these are controlled, laser utilization results so comfortable to be well accepted also in paediatric patients[46].

This study, even if it may be considered as preliminary due to the limited number of the samples and also by the limits related to the differences between the “ex vivo” and “in vivo” models, opens a new perspective on the laser oral soft tissue surgery, proposing the utilisation of a new wavelength.

In fact, we may conclude that, among the different lasers used, the quality of incision was better and the thermal elevation lower in the specimens irradiated at shortest wavelength (450 nm).

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