The Delta Cube laser: a multi-wavelength diode laser

Part I: "Ex vivo" study

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Fig. 1

Fig. 1_Complete view of the device.

_Introduction

Diode lasers are currently in relatively widespread use in dentistry for a number of reasons including their compact design, ease of use and range of applications in the field. It should nonetheless be noted from the outset that the indications are limited to soft tissue (exeresis) and only to the superficial treatment of hard tissue (disinfection) without exeresis.

Diode lasers are semi-conductor lasers and have variable wavelengths ranging from visible to infrared. It is now possible for the same device to emit several different wavelengths, one, two or three at the same time. The Delta cube laser is interesting in this regard, as it provides four different wavelengths (405 nm blue aiming beam, 650 nm diode and 915 and 1,064 nm diodes).

_Brief description of the device

The power ranges from 0.1 W to 15 W, which allows the Delta Cube laser to be used where low-powered lasers are indicated (less than 0.5 W, Nogier frequency) and also for cutting and disinfection with higher power settings. The frequency is also variable (20 Hz-50 Hz-100 Hz and 20 kHz). The device has a display (Fig. 1) of the selected parameters, which can be changed with pushbuttons. There is a display for surgical procedures at the bottom of the device which shows the pre-programmed settings corresponding to various surgical procedures.

At the top left (seen from the front) is a purple tip which is primarily used for hemostasis and combines two wavelengths (1,064 and 915 nm) and the aiming beam (405 nm). Below is a green tip for straight cutting and below that a red tip for cutting at an angle of 90° (combination of the three wavelengths). This is the first time that a "dental" diode laser has been available in non-contact mode, and this feature is why an aiming beam (blue) is required. At the top right, a metallic tip provides low power output and is used inter alia to manage post-operative and joint pain (red laser, 650 nm and 915 nm); the diameter of the spot is 6 mm. Below, there is a yellow tip for positioning fibres of varying diameters (usually 400 µm), used in endodontics and periodontics in the disinfection process. Magnetic force means that all the tips are easily manoeuvred with the handpiece which

Fig. 2a

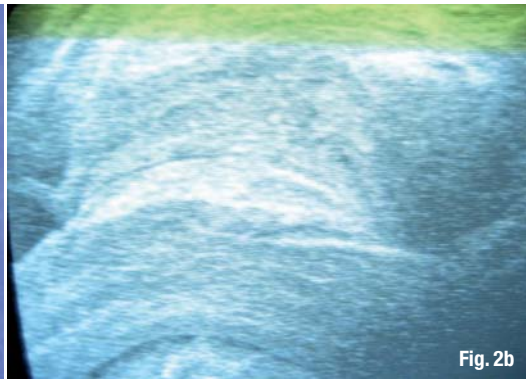
Fig. 2b

Figs. 2a & b_Incision 7 W. Precise edges. The tissue retraction is a result of the desiccation and subsequent bonding (observation with SEM).

holds the fibre. This magnetic force facilitates handling. There is an emergency stop button on the bottom of the instrument which cuts off the electricity supply.

Ex vivo tests

The choice of parameters and their effects is an issue to be addressed with any new device. Initially, *ex vivo* tests are needed to reproduce or to attempt to reproduce clinical conditions.

Relationship between cutting and temperature increase

Three power outputs were tested (3 W, 5 W and 8 W) with the green tip (straight cut) and the red tip (90° cut) on animal jaws. These power outputs have been correlated with an increase in temperature of the underlying tissue (Lesnik-Cannavo and Bertrand MF). A control group was taken with a cold blade (no. 15) and the irradiated areas were irradiated in successive passages of the laser. Irrespective of the method used, the cut was checked with a metal probe to test the depth of the cut (down to the periosteum) (Fig. 2).

The best results were obtained with a power setting of 7 W (duration of each pulse: 300 msec, frequency: 100 Hz). Few traces of carbonisation were observed. Cutting can be initiated even more rapidly if a black dot is applied to the biological tissue using a felt-tip pen, as there is high absorption of the combination 1,064 nm and 915 nm by this colour (chromophore). In these ex vivo tests, the thickness of the tissue (1.2 mm to 1.5 mm) was much greater than that found in vivo in people. The same applies to the texture, which is much more compact in the experimental model. In the light of these two aspects, cutting requires more clinical time *ex vivo*. In this model, the total number of pulses at 7 W was 27,926 for a 10.5 mm-long incision line, which is equal to 2,660 pulses per centimetre of incision. This represents 26.6 seconds per centimetre of incision at a frequency of 100 Hz. The temperature increase measurements were conducted on the same tissue using the following parameters: incisions 1 and 2 = 3 W (power density = 9,554.14 W/cm²); incisions 3 and 4 = 5 W (power density = 15,923.56 W/cm²); incision 5 = 8 W (power density =25,477.70 W/cm²). A thermocouple was placed under the mucous tissue and moved in line with the location of the incision lines to be under the line of irradiation. The temperature increase at 3 W was 2.27 °C in 10 seconds for a power density of 9,554 W/cm². It was 2.51 °C in 10.06 seconds at 5 W (power density: 15,923 W/cm²) and 3.68 °C at 8 W (power density = 25,477 W/cm²).

These ex vivo tests indicate that, no matter what the power used, the temperature increase measured in these experimental conditions is never excessive and meets the limit of 7 °C, above which protein coagulation can be observed.

Temperature increase and periodontics

Disinfection of the pockets is a stated objective, and while there are several methods are available,

Fig. 3a

Fig. 3b

Figs. 3a & b_Positioning of the thermocouple and its movement in line with the incision line.

Fig. 4_Temperature increase at 3 W.
Fig. 5_Positioning the thermocouples.

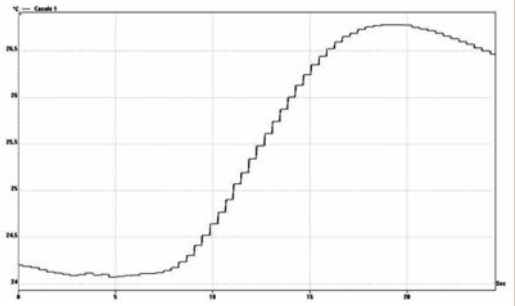

Fig. 4

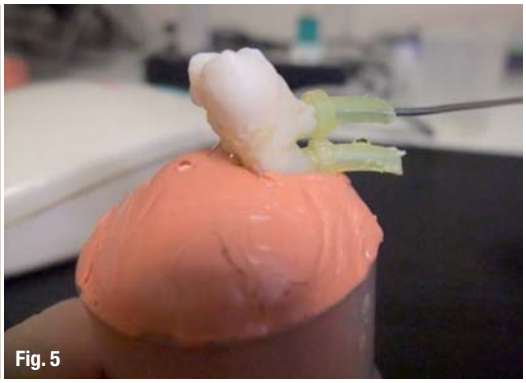

Fig. 5

laser technology is one of the possible therapeutic options. It must therefore be ensured that when a fibre is at the bottom of the pocket and therefore in contact with the cementum, there is no temperature risk to the pulp.

Freshly extracted monoradicular teeth were preserved for a brief period of time in saline solution at 4 °C and the root canals were prepared using the Protaper® system, with irrigation with a 2.5 % sodium hypochlorite solution. The samples were fixed in silicone and two metallic tubes were attached to the cervical third and the apical third of each of the roots. Two thermocouples were inserted into the hollow tubes, filled with conductive gel, in contact with the radicular dentin opposite the areas irradiated. The thermocouples were connected to the data acquisition system (Picolog®).

Two periodontal pockets were simulated by creating pockets in contact with the cementum. These pockets were irrigated with oxygenated water with a small quantity of Betadine®, acting as a chromophore for wavelengths of 1,064 and 915 nm. Radiation was from the bottom of the simulated pocket towards the coronal part. The irrigation solution was changed after each cycle. Each cycle lasted 5 sec. and the intervals were 5 sec. A total of 5 cycles were observed per canal. The fibre (yellow tip) was used with power densities of 2 W, 4 W and 7 W, and two frequencies (100 Hz and 20 kHz). The measurements recorded did not indicate a temperature rise of more than 4.13 °C at any frequency, power density or position.

Temperature increase and endodontics

Once the canal had been prepared by irrigation with hypochlorite, two thermocouples were placed in contact with the cementum and the laser fibre (yellow tip) was positioned 1 mm from the operating depth. The canal was irrigated with hypochlorite and a small quantity of Betadine; irradiation was from the apical section to the coronal section. Each cycle lasted 5 sec. and the intervals were 5 sec. Five cycles were conducted, equivalent to a clinical time of around one minute. The power outputs used were 2 W, 4 W and 7 W as in the preceding tests and the maximum temperature rise was 4.16 °C, which is almost identical to that observed when the optical fibre was placed in contact with the cementum. In endodontics, this type of laser does not remove the smear layer; this has to be done using traditional methods (17 % EDTA or 11 % citric acid). Once the smear layer has been removed, the root canal can be irrigated with hypochlorite (2.5 % to 5.25 %). Near-colourless (yellow) hypochlorite does not stop these wavelengths and as the fibre is at ca. 6 mm above the operating depth, it must be activated in a spiral movement back towards the crown. A biologically neutral food colouring can be added to the irrigation solution for maximum absorption of these wavelengths. In vitro tests on a resistant bacterium (*Enterococcus faecalis*) show a significant reduction in the bacterial load. Furthermore, the light can reach 1,100 µm and therefore penetrate the accessory canals and dentinal tubules.

Discussion

Diode lasers are thermal lasers absorbed deep in the target tissue like other non-semiconductor lasers such as Nd:YAG, Nd:YAP, and to a lesser degree KTP lasers; CO_2 lasers act differently in this regard (superficial absorption, non-fibre). Avoiding all temperature damage is an objective that can be achieved provided certain simple principles are followed:

- Comply with the intervals. This can be done by using low frequencies at the risk of extending the operating time, or simply by ensuring that the intervals are equivalent to the operating times (endodontics, periodontics);
- Move rapidly (incision, excision) and do not hesitate to go back over the line, as this prevents thermal shocks;
- Initialise cutting with a black dot applied with a felt-tip pen, and start to irradiate this dot. Wavelengths 1,064 and 915 nm are absorbed by the colour black, so this enables the rapid start of cutting;
- In disinfection procedures, the fibre (yellow tip) should move relatively rapidly and from the bottom of the pocket or from the operating depth (en-

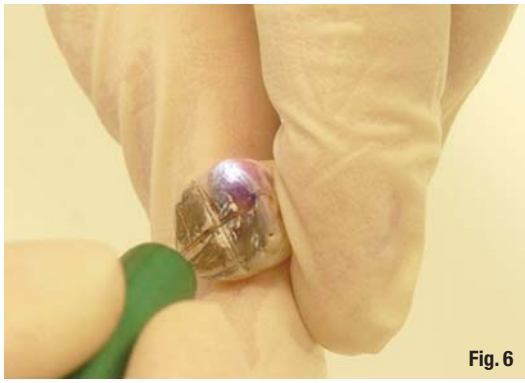

Fig. 6

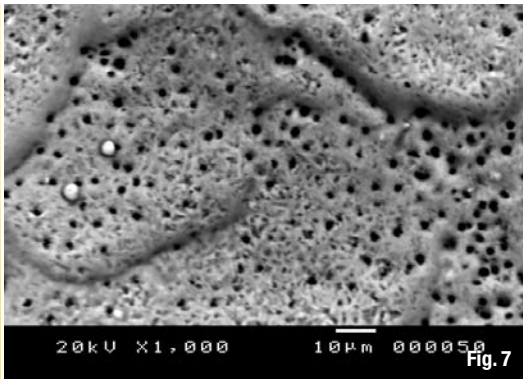

Fig. 7

Fig. 6_Graphite application and irradiation.
Fig. 7_Partial closure of the dentinal tubules (output power 1 W).

dodontics) towards the crown in a spiral motion. The use of a colouring facilitates absorption.

_Treating dentinal hypersensitivity

Hydrodynamic theory links the movement of intratubular fluids to the occurrence of dentin hypersensitivity characterised by acute but brief pangs of pain. A number of different methods have been proposed for managing this syndrome, with varying degrees of success. The objective is however the same in all cases: to close the opening of the dentinal tubules to prevent the movement of these fluids. An experiment was conducted in which discs of dentin were prepared and the smear layer removed, and the opening of the dentinal tubules was then monitored with a scanning microscope in a partial vacuum. The surfaces were then separated into four distinct sections (Fig. 6) and coloured using a black graphite pencil. The surfaces were irradiated with four different power outputs: 0.5 W, 0.75 W, 1 W and 1.5 W for a period of 2 mn per section.

The partial or total closure of the dentinal tubules can be achieved in these irradiation conditions, and in particular with a power output of 1 W. This output is sufficient to achieve the desired results without a temperature increase in the pulp (below 5 to 7 °C at all times). It is nevertheless always important to check the presence of graphite on the irradiated surface, to move tangentially to this surface as far as possible, and never to apply the laser without movement.

_Discussion

There have as yet been no publications on this new laser diode concept combining different wavelengths, but in the light of these initial ex vivo observations, the following remarks can be made. In terms of ease of operation/handling, apart from the compact design which is standard for diode lasers in general, the originality of this device is the magnetic connection for the tips. The tip of the handpiece can be removed for changing extremely rapidly. A roller device at the side facilitates storage of the fibre. This is also the first diode laser able to be used in non-contact mode, including an optical system for cutting with a handpiece at 90°. In difficult areas where the fibre cannot be used, this handpiece makes access to these difficult zones possible (for example the distal face of the maxillary molars). Combining 1,064 nm – 915 nm makes it possible to achieve a clean cut for surgical procedures in soft tissue in a bloodless environment. The use of higher frequencies (20 kHz) makes it possible to obtain peaks in power loosely referred to as "pulses". In a clinical setting, this should enable narrow incisions without heat damage, as demonstrated ex vivo.

Lastly, the more or less systematic use of low-energy lasers in surgical procedures (metallic tip, 650 nm) facilitates healing and merits systematic use. Future studies should examine clinical observations with different indications, such as standard surgical procedures (soft tissue) in adults and in children, pathology applications such as the management of herpetic and aphthous lesions, disinfection in endodontics and periodontics, the treatment of periimplantitis, tooth whitening and the management of joint pain and healing processes._

_contact laser

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