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COMMENT

# The blue wavelengths in laser dentistry: a review of current literature

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**Abstract**
Dental laser applications are steadily increasing in popularity amongst dentists for the last four decades. Although many wavelengths are available for practitioners, semiconductor lasers or commonly known as diode lasers, are still the most popular ones. Dental diode laser devices are available in wavelengths that belong to visible and near infrared region of the electromanetic spectrum. Recently, lasers that are in the area of 400–450 nm have emerged in the market and became available to dentists. In this article, we aim to analyze the clinical possibilities we have with these lasers according to the available literature that has been published so far.

**Keywords** Diode laser · Blue laser · Diode · Soft tissue

Lasers in dentistry have reached their fourth decade of existence. Their infiltration to dental clinics worldwide is mainly evident the last decade and many clinicians are using these high-end technological devices in almost all indications of dentistry. By definition, not all laser devices are capable of executing the same operation and we categorize them according to their emitted wavelength. Due to their simplicity, portability, and affordable price, most dentists enter the laser dentistry world by purchasing a semiconductor or commonly known as a diode laser.

Diode lasers in dentistry are available in many different wavelengths which belong in the visible and near-infrared parts of the electromagnetic spectrum. All of them are used in soft tissue operations, i.e., incisions, excisions, microbial load reduction, teeth whitening, and photobiomodulation. The differences between all wavelengths are existing and these are related to the specific absorption coefficient of tissue components to the incident laser beam wavelength.

One of the latest diode wavelengths that have been added to the dentist's armamentarium is the so called "blue wavelength," which is belonging to the visible spectrum and its wavelength can be 445 or 450 nm. The semiconductors used as active medium on these devices can be different materials, such as ZnSSe, ZnSe, or CdZnSe. Their characteristic is that those wavelengths present the highest absorption in hemoglobin $\mu A_{(Hemoglobin)} = 1404\ cm^{-1}$, in melanin $\mu A_{(Melanin/Skin)} = 1033\ cm^{-1}$ and the lowest absorption in water $\mu A_{(Water)} = 2.8{\cdot}10{-}4\ cm^{-1}$), amongst all other diode lasers of visible and near infrared spectrum that are used in Dentistry today [1].

In the vast majority of available dental devices today, 445-–450-nm wavelength is present on the preset parameters of surgical procedures. With regards to absorption spectra and increased scattering in the blue wavelength region, we can clinically observe better cutting effects than the rest of NIR diode lasers used in dentistry which even can become evident without tip initiation or even in non-contact mode treatments. On the other hand care must be taken in the output power levels as unwanted thermal effects can occur faster than in the NIR region. This has been reported by Braun et al. when compared with a 970-nm diode laser and a high-frequency surgical device [2].

A clinical study was published by Agha et al. regarding gingival hyperpigmentation in comparison with other two wavelengths, namely 2780 nm and 940 nm. Although the number of patients for each group was relatively low (*n*=10), positive results similar to the other two

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wavelengths were reported for 445 nm. Output power was set at 0.3 W in CW mode of operation with a 320-μm fiber. Statistically significant results differ only in the observations of operational time (445 nm and 940 nm were faster than 2780 nm) and postoperative pain which was observed higher for 445 nm. There were no statistically significant differences between the 3 above mentioned wavelengths with regards to bleeding, healing and color improvement and patient satisfaction.

A very interesting ex vivo study was published by Hanke et al. comparing eight different wavelengths between 400 and 1500 nm in incisions made by a robotic device under the same parameters. The histological study evaluated the cutting behavior of those wavelengths and specifically cut depths, cut widths and thermal effects in the surrounding areas of the incisions. In this study 445 nm had the best cutting depth from all other wavelengths. Also the blue wavelengths (405 and 445 nm) alongside the green diode lasers (514 and 532 nm) had better thermal expansion profile, meaning that less output power is needed in order to achieve a good incision in gingival tissue in comparison to than near infrared diodes (810, 940, 980, 1064 nm) [3]. The increased cutting efficiency of 445-nm diode laser was also confirmed bt Braun et al., when compared to a 970-nm diode laser and high-frequency surgery.

Regarding thermal effects and microbe reduction in endodontic treatments, two studies so far can be found in the literature. The first one was by Gutknecht et al., where an in vitro experiment measured the microbe log kill in autoclaved human dentin slices of different thicknesses (1000, 500, and 300 μm). One side of the slice was inoculated with 1 ml of a defined concentration of a standard ($2.0 \times 10^7$ CFU/ml) Enterococcus faecalis (strain ATC 29212) suspension and the irradiation with a 445-nm diode laser was executed from the opposite side with different output powers both in CW and chopped mode of operation. Superior results in log kill of Enterococcus faecalis under the protocol used were recorded in both groups (CW, 0.6 W) and chopped (1.2 W peak, Duty Cycle 50%), although the authors suggested that CW mode of operation would be preferable in order to achieve a more homogeneous energy distribution profile in dentine [4].

Alshamiri et al. tested the temperature increase on teeth roots during laser-assisted endodontic treatment with a 445-nm diode laser. Although the sample of single-rooted teeth used was low ($n$=15), the authors concluded that under their specific protocol all tested power settings (0.6 W CW, 0.4 W CW, 1.2 W peak, 10 Hz, 50-ms pulse duration, and 50% duty cycle) were found safe for the surrounding tissues as none exceeded the 10ºC threshold [5].

Deppe et al. have tested under an in vitro experimental setup the thermal impact of blue light irradiation on five types of dental implants. The 445-nm wavelength-induced temperature increases of more than 10 °C at or above 0.8 W power working in CW mode for 5 s and in gated mode at 3 W for 20 s with 10% duty cycle, which means that it is contra-indicated to clinically use blue diode at this output powers in peri-implantitis treatment, as it might negatively affect the osseointegration [6].

In the case of laser-assisted whitening, there are still no data found of the literature but theoretically it could be a very promising wavelength, if the safety of the pulp can be proven by testing different output powers. In order to have maximum absorption in the bleaching gel, one must look at the complimentary color chart where blue is compatible with orange, giving us a clue on the preferable color of the oxidizing agent.

Regarding photobiomodulation, blue diode wavelengths are outside of the activation spectrum (600–1000 nm) of the major PBM photoreceptor which is cytochrome C-oxidase. Also a few studies in the past have shown reduction of proliferation and metabolic activity after 453 nm irradiation (200 J/cm$^2$) and suppresive effects on mouse dermal fibroblasts after blue LED light irradiation (4 & 8 J/cm$^2$). Nevertheless, a preliminary in vitro study of Etemadi et al. managed to achieve encouraging results with regards to cultured human gingival fibroblast cell proliferation and migration, under low energy densities of 4 and 6 J/cm$^2$ [7].

Blue laser and PDT have also only one study published so far. Katalinic et al. Under their study protocol, it was concluded that 445 nm (peak power 200 mw, 50% duty cycle) with a combination of 0.1% riboflavin solution (yellow/orange) had significantly better antimicrobial effect (E. faecalis, S. aureus and C. albicans) than photo-thermal microbe reduction (445 nm–445/970 nm) [8].

So far, 2 other blue laser studies have been published with regards to other operative dentistry treatments. The first one is an in vitro study by Kouros et al., where a 445-nm diode laser was used to cure composites. Laser curing with 0.7 W resulted in statistically significantly higher maximum temperatures than did LED curing for both 1 mm thick (52.9°C against 45.4°C) and 3 mm thick (43.6°C against 40.9°C) specimens. The study concluded that blue diode laser (445 nm) may be an alternative for photopolymerization of composite materials and may result in a higher degree of conversion and depth of cure of composites than what has been seen with LED curing units when they emit at the same energy density [9].

Moreover another in vitro study by Morsi et al. measured the induced temperature elevation in the case of using a 445-nm diode laser to treat hypersensitivity by irradiating the cervical third of extracted human single-rooted teeth. Here again, the sample number was low ($n$=10) and the report resulted in safe temperatures only when the diode laser was used in a distance of 1–2 mm from the treatment area and under constant fiber moving of the operator in a scanning mode [10].

Blue diode wavelengths have certain characteristics like very high affinity to hemoglobin and melanin plus a very low affinity to water that make them very interesting in soft tissue dental interventions. On the other hand, the fact that inexperienced and uneducated dental laser users are using them as “another dental laser diode” makes them a potentially dangerous tool as thermal effects can be very dramatic, especially in cases where dentists are copying protocols from NIR diode lasers. There is certainly a need for more evidence-based studies in different indications in order to have more sound data not only on the advantages, but also on the limitations of these very promising wavelengths.

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## Declarations

**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** Not applicable.

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