SPECIAL REPRINT:

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Taking a new approach – the 445-nm laser in clinical applications

In cooperation with Dentsply Sirona
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**Keywords**
Diode laser, semiconductor laser, blue laser, periodontitis treatment, incision, excision, bacterial reduction

**Summary**
Laser systems are used in a variety of dental treatments, particularly in the fields of surgery, restorative dentistry, endodontics, and periodontology, in order to improve both the patient’s comfort and the treatment result. The effectiveness of the laser crucially depends on how the tissue absorbs the electromagnetic radiation. The development of a new kind of diode laser in the blue wavelength range (445 nm) promises good energy coupling to pigmented cells and tissue. Combined with low absorption in water, the cutting performance for surgical procedures is superior to conventional semiconductor lasers in the wavelength range 810 to 980 nm. Furthermore, blue laser light is an ideal way to improve standard methods of bacterial reduction in periodontal lesions and root canals. This overview illustrates and discusses the clinical applications with the new 445-nm laser technology, as well as current study results. The range of applications of the blue light laser is presented here based on clinical cases.

**Laser applications in dentistry**
Laser treatment is not just an alternative to conventional procedures in a variety of medical fields, such as ophthalmology, otorhinolaryngology, vascular surgery, and dermatology, it has also allowed for the development of new treatment protocols. Taking existing data into account, the specific features of lasers, such as heat development or limited tactility, are negligible when laser systems are used properly and for their intended use, and are not detrimental to the treatment result. The laser has successfully established itself in three main areas of dentistry: surgery, endodontics, and periodontology. Here, semiconductor and diode lasers are the
The effect of a laser is based on the principle of absorption of its electromagnetic energy into the tissue, and conversion into another form of energy. With regard to the laser power used, there is a difference between soft and hard lasers (Table 1). This distinction characterizes the therapeutic area of application of the laser: Soft lasers with low power in the low milliwatt range primarily cause a biostimulating effect during laser phototherapy, while higher-power hard lasers tend to work invasively. However, there is no specific boundary between soft and hard lasers, as biostimulation and invasive effects, such as photoablation or photodisruption, do not just depend on the power settings of the laser, but also on the laser wavelength used.

During laser treatment, a variety of parameters that can influence the success of the treatment must be taken into consideration, which include the parameters of the laser radiation itself (wavelength, power, operating mode, duty cycle, frequency), as well as the surrounding medium (air, water, blood), target tissue (absorption coefficient, heat conductivity), and handling (speed, distance, angle of incidence, fiber diameter). The absorption and penetration depth parameters are the most important for the indication and therapeutic success; the more absorption, the lower the penetration depth in the tissue, and vice versa. The materials water, hemoglobin, porphyrin, pigment (melanin), and hydroxylapatite are particularly relevant for dentistry, as they absorb the laser energy in various intensities, primarily...
depending on the wavelength, power, and duration of radiation. The practitioner can control these parameters to achieve the intended photochemical, thermal or ablative effects16.

The different lasers have wavelengths with different characteristics; a shorter wavelength means more energy intensive laser radiation. Nd:YAG lasers work with 1,060 nm, Er:YAG lasers with 2,940 nm, CO2 lasers with 10.6 μm (10,600 nm), and diode lasers with shorter wavelengths of 400 to 1,000 nm. Recently, the selection of diode lasers used in dentistry was extended to include a blue wavelength4. The primary indication for a 445-nm semiconductor laser (SiroLaser Blue, Dentsply Sirona, Bensheim) is in the area of invasive hard lasers. However, initial study results that have not yet been published also indicate biostimulative effects.

Lasers in the blue wavelength

What distinguishes the wavelength 445 nm from other wavelengths? Blue light is less readily absorbed in water compared to conventional semiconductor laser systems (Fig 1) and does not penetrate as deeply into tissue due to its short wavelength4. The absorption peak for pigmented cells is in the range of approximately 430 nm2,14. Due to the high absorption and therefore energy input, the 445-nm diode has a higher cutting performance than infrared laser light. This allows a cut to be made in the upper tissue layers using a non-contact procedure, which is not possible with conventional semiconductor lasers in the higher wavelength range. Since the fiber does not have to be placed on the tissue, coagulated blood does not form at the tip of the fiber, which makes it even more practical because the fiber does not require repeated cleaning. Due to immediate coagulation, the practitioner maintains a clear view of the operating field, allowing for precise work.

Indications for using a 445-nm laser

The possible applications of a 445-nm laser (Fig 2) cover almost all areas of dentistry (Table 2). Surgical procedures, such as maxillary frenectomy, can be carried out very effectively under these conditions. In the frenectomy case shown in Figures 3 to 6, laser power starting at 1.6 W in continuous wave mode was enough to separate the upper layers of tissue in non-contact mode because the tissue was well supplied with blood. The parameters were changed to 2 W in the deeper fiber area, and the cuts made to detach the frenulum from the periosteum were carried out in contact mode. Using the blue laser light ensured that the operating field remained almost blood-free and the working area was kept clear.

When removing an operculum from the underside of tooth 38 (Figs 7 to 10), the 445-nm laser was operated at 1.8 W in CW mode. The precise direction of the radiation via the fiber reduces the thermal input into the surrounding tissue so that a very limited and controlled development of heat can be assumed (Fig 11). If the laser is used correctly, there should be no risk of accidental injury to deep or adjacent structures, such as vital pulp, for example, during disinfection of periodontal lesions. Our own ongoing studies suggest that there is no clinically relevant temperature increase when using the 445-nm laser, similar to polymerization lamps5.
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Fig 2 Laser system with the wavelengths 445, 660, and 970 nm with preselected laser parameters and attachable work pieces of different fiber diameters for the specific indication.

Fig 3 Labial frenulum deep in the papilla with limited lip mobility.

Fig 4 Maxillary frenectomy with detachment of the fibers from the periosteum with a 445-nm laser. Use of a 320-μm fiber at 2 W in continuous wave mode.

Fig 5 Situation 1 week after frenectomy. Non-inflamed wound with the expected fibrin coating and no evidence of secondary bleeding.

Fig 6 Wound follow-up 1 month after the maxillary frenectomy. Wound area completely healed, no impact on mobility of the upper lip.
Further indications

In an ongoing, clinically controlled, prospective parallel case study, our working group is investigating bacterial reduction with the 445-nm laser system during endodontic treatment. A previous in vitro and in vivo investigation showed that the use of a 445-nm diode laser eliminated further bacteria after prior conventional rinsing with sodium hypochlorite. This result suggests that adjuvant application during a conventional chemomechanical root canal treatment can result in extensive elimination of bacteria that would otherwise be left in the root canal system.

For bacterial diseases, systematic periodontitis treatment is another possible indication for blue laser technology. An in vitro pre-investigation showed that periodontal pathogens could be killed with the 445-nm laser. In the near future, an ongoing, multicenter, prospective, clinically controlled in vivo study will be able to show a possible adjunctive effect on the healing of diseased periodontal tissue.

Table 2 Indications for using a 445-nm laser. The list includes described or derived areas of application

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<tr>
<th>Area</th>
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<th>Application</th>
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<td>Hemostasis</td>
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<td>Wound healing</td>
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<td>Wound healing</td>
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<td>Periodontology</td>
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<td>Orthodontics</td>
<td>Loosening of composite</td>
<td>• Bracket removal</td>
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Fig 7 Flap of tissue (operculum) over the partially erupted tooth. The patient complained of recurring infections of the overhanging tissue.

Fig 8 Operculectomy with a 445-nm laser. Use of a 320-μm fiber at 1.8 W in continuous wave mode.

Fig 9 Situation post-surgery without signs of heavy bleeding.

Fig 10 Clinical situation 2 weeks after an operculectomy. Non-inflamed wound with a slight fibrin coating.

Fig 11 Thermographic representation during a tissue incision. Local heat development in the working tip area (red marking).
excision with 2 W in CW mode and a 320-μm fiber – carbonization is avoided, and a tissue sample suitable for histological evaluation is acquired (see Fig 4).

For surgical procedures to remove or shape the gingiva (gingivectomy/gingivoplasty), the 445-nm laser is a gentle alternative to a scalpel or electrosurgical instruments. This also applies to laser application used to treat inflammation of soft tissue on a partially erupted tooth (pericoronitis).

Geriatric dentistry aims to apply the most minimally invasive treatment concepts. Removing fibromas as part of systematic treatment of fibromatous denture stomatitis can be considered an age-appropriate method that is gentle for the patient, as severe bleeding is avoided.

Another surgical option is implant exposure, as the coagulating effect of the 445-nm lasers leads to minimal bleeding and foreseeable wound healing. Thermal effects on the implant can be avoided when used according to protocol.

**Evaluation**

The properties and effects of laser radiation, particularly with a wavelength of 445 nm, can be evaluated as less invasive compared to conventional treatment methods. During surgical procedures, the shorter wavelength of the blue laser light prevents it from penetrating as deeply into the tissue as conventional semiconductor lasers. This lower penetration depth reduces the risk of unintentional injury to the deeper layers, and beam guidance can be more precise. The thermal energy input of the laser in the surrounding tissue is reduced due to the low absorption of water, which results in incisions with limited bleeding and heat spread. Minimum cell damage, less bleeding, foreseeable wound healing without scarring, and negligible postoperative edema with reduced intake of analgesics after the procedure could be observed. Compared to conventional treatments with a scalpel or electrosurgical instruments, the laser preserves tooth substance to ensure that only the necessary tissue is removed, and that there is a very low risk of damaging the deeper structures.

Treatment with the laser causes minimum wound pain, but is not completely pain-free. Since sutures are generally not needed in smaller surgical procedures, there is no need for a second procedure to remove them. The higher cutting performance of the 445-nm laser compared to conventional infrared semiconductor lasers (including in non-contact procedures), together with a mostly bloodless operation site, makes handling of the laser easier.

A definitive statement on periodontal and endodontic bacterial reduction, which has already been clinically proven for wavelengths in the infrared range\(^1,3,8,12\), can only be made once ongoing studies have been completed. However, initial results of antimicrobial effects with the 445-nm laser already indicate corresponding areas of application.

**Outlook**

Experience to date with the 445-nm laser in surgery, endodontics, and periodontology has been positive. Furthermore, the results of the first studies conducted show that the blue wavelength can also induce biostimulative effects as part of low-level laser therapy (LLLT) to support wound-healing processes. Initial attempts to use the blue laser light for localized tooth whitening are promising, and could offer another application option in dentistry.

In many cases, treatment procedures based on laser technology alone appear to yield results that could also be achieved with conventional methods. However, when laser-based treatment methods, such as the use of the 445-nm laser, are considered as adjuvant treatments, they can improve the results of conventional treatment protocols and have a positive effect on the overall treatment success. Therefore, it is possible that blue laser light will be established as part of standard treatments in the future.
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References

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