Absorption of laser energy

When laser energy meets human tissue, part of the energy is reflected, depending on the angle of incidence. The energy that penetrates the tissue is either transmitted unchanged, scattered, deflected, or absorbed, and transfers the respective amount of energy to the absorbing molecule. In connection with this, various kinds of interaction with the tissue such as photochemical, thermal, or ablative effects can be observed. In human tissue, laser energy can be absorbed by water, porphyrin, hemoglobin, melanin, or hydroxyapatite, for example. Which biological structures react to laser light, and how they react, depends on the wavelength of the laser light, the power, and the duration of radiation (Tab. 1).
Non-thermal semiconductor lasers

With regard to the effects of semiconductor lasers used in medicine, a basic distinction can be made between non-thermal and thermal effects. In the case of non-thermal effects, the capability of using the transmitted energy to trigger a photochemical reaction is exploited. A typical example of this is antimicrobial photodynamic therapy (aPDT). This is a method of affecting cells, microorganisms, or molecules by low power density laser energy. For this purpose, three components are needed in order to have an effect at the target site: energy (here in the form of laser light), a light-activated agent (photosensitizer), and oxygen. The photosensitizer is activated by laser energy in such a way that energy can be transferred to the oxygen present, resulting in cytotoxic effects on microorganisms. Even microbes such as Enterococcus faecalis that are problematic for endodontic treatment can be eliminated from root canal systems.

Conventional semiconductor lasers

When utilizing thermal effects, there is a gradual, selective reaction in tissue structures depending on the degree of heating. The reactions when a conventional diode laser with wavelengths of 810 to 980 nm is used are often coagulation and removal of tissue through photoablation. Depending on the laser parameters, diode lasers such as this can be used for coagulation cutting or ablation of oral soft tissue. Such techniques are useful for providing an essentially blood-free surgical field and reducing the bacterial colonization of periodontal lesions. For chronic periodontitis, slightly better clinical parameters have been observed with adjunctive treatment with a 980-nm diode laser than after conventional treatment. Since no clinically significant improvement has been ascribed to the adjunctive diode laser treatment of periodontal lesions in other studies, additional investigations are needed in this area in the future. However, the results are clearer in other fields of dentistry. For root canal preparation, for example, a significant improvement in microbioreduction was found for adjunctive laser treatment compared with rinsing with sodium hypochlorite alone. Furthermore, an antibacterial effect extending to the depth of the dental hard substance was proven when a 980-nm diode laser was used.

Blue laser technology

Semiconductor lasers are being used in an increasing number of fields in research, industry, medicine, and to no small extent the consumer sector due to their compact structure, high optoelectric efficiency, and reliability. They have become indispensable even for daily use such as in laser pointers, CD ROMs, Blu-Ray storage formats, laser printers, distance measuring devices, and barcode scanners, and for data transfer and storage. In recent decades, great efforts have therefore been made to develop semiconductor lasers with certain wavelengths.
The 445-nm semiconductor laser in dentistry – introduction of a new wavelength

The first person to present the gallium nitride laser diode in the blue light range with a wavelength of 405 nm. For this, he and his colleagues, Isamu Aksaki and Hiroshi Amano, were awarded the Nobel Prize for Physics in 2014.

The wavelength used is of major significance for the therapeutic effect. This is due to the absorption properties of the irradiated tissue, as the interaction with the tissue is determined by the energy input into the tissue. High absorption of laser energy in the tissue results in a low penetration depth, and vice versa. For coagulating cutting in surgical procedures, there should therefore be high absorption rates in tissue and blood. In such procedures, one of the most important advantages of blue laser light is that, due to its shorter wavelength, it penetrates less deeply into tissue and is scattered less\(^{14}\). In turn, due to this low penetration depth, the risk of accidental injuries in deeper layers is drastically reduced and the beam can be guided more precisely. At the same time, the thermal input to surrounding tissue from the scattering of the laser light is reduced.

If we look at the individual components of human and animal tissue, they contain high percentages of water, hemoglobin, melanin, lipids, and proteins. The absorption maximum for blood cells is in the range of approximately 430 nm\(^2\,^{10}\) (Fig. 1), which leads to a high energy input and can thus cause rapid coagulation. However, the absorption rate for water is not high in this wavelength range, so limited heat buildup from energy input into water can be expected. For surgical procedures, blue laser thus allows clean cutting with little bleeding and a limited area of heat generation due to the special absorption properties in the tissue components.

**Case report**

At the beginning of October 2014, a 44-year-old female patient presented at the Medical Center for Dental and Oral Medicine in Marburg. She reported a lentil-sized mucosal lesion in the vestibular area of her right lower lip that she had first noticed a few months previously (Fig. 2). With the suspected diagnosis of traumatic fibroma, photo documentation was made in order to record any changes in the size and surface structure and also the reaction of the adjacent tissue. Although according to the patient no significant change had taken place since the lesion was first noticed, she expressed the desire to have it removed. The patient was offered the option of laser removal as an alternative to conventional removal with a scalpel and subsequent suture. With this treatment method, it could be assumed that, given the coagulating effect of the laser, sutures would not be necessary, thus avoiding also the necessity of a second procedure to remove the sutures. Treatment was scheduled for 30 October 2014, to give the patient sufficient time to give her consent to the surgical procedure.

To remove the lesion, the SIROLaser Blue (Sirona, Bensheim), a Class IV 445-nm diode laser, was used (Fig. 3). For the tissue excision, the manufacturer recommended a setting of 2 W in continuous wave (cw) mode and a resulting duty cycle of 100%. The hand-
The 445-nm semiconductor laser in dentistry – introduction of a new wavelength

A piece was used with a 320-µm (core diameter) fiber and was activated via the finger switch.

Since the patient had no conspicuities in her general medical history, Ultracaine D-S 1:200,000 (Sanofi-Aventis, Frankfurt a. M.) was used for local anesthesia, with a total of 0.9 ml used for circular infiltration around the tissue to be removed. Following a check of anesthesia using a sharp probe in the surgical area, the patient and surgical team all put on laser safety goggles suitable for a wavelength of 445 nm. The treatment room was designated as a laser workplace from the outside. In addition, a warning light located at the entrance door to the treatment area was activated.

After the mucosal lesion had been grasped with a surgical forceps, the tissue was excised by guiding the fiber from mesial to distal horizontal to the surface of the healthy tissue (Fig. 4). Unlike conventional diode lasers, it was not necessary to condition the fiber with the 445-nm diode laser. The mucosal lesion was separated *in toto* from the tissue substrate by applying slight tension with the surgical forceps (Figs. 5 and 6). Due to the coagulating effect of the laser, there was no acute bleeding which would have required a suture. The area of the wound was flushed with normal saline solution to clean and moisten the tissue. The excised tissue was placed in a prepared container of formalin and sent directly to the Marburg Institute of Pathology for histological examination (Fig. 7).

After Solcoseryl dental adhesive paste (Valeant Pharmaceuticals, Bad Homburg) was applied to the wound surface, the patient was advised to protect this area as much as possible. She was also given the option of taking a pain tablet should she experience pain once the anesthetic had worn off. She was told to avoid eating if possible while the anesthetic was still effective in order to prevent unchecked biting into the oral mucosa. The patient was requested to return for routine wound checks 2 and 7 days after the procedure. A non-irritated wound with the expected fibrin coating was found at follow-up (Fig. 8). No postoperative hemorrhaging was seen or reported by the patient.
The latest wound follow-up was made 1 month after the procedure. At this time, the wound was completely healed and no new tissue formation was detected (Fig. 10). No scarring was detected on inspection or perceived when eating. The patient reported that she had felt a burning sensation at the tissue removal site during the healing process, but that there was now no pain or dysesthesia in the area. Another follow-up should be made 6 months from now as part of a routine dental check-up.

The Marburg Institute of Pathology described the excised tissue after HE (hematoxylin eosin) and PAS (periodic acid Schiff) staining as follows: 0.3 x 0.3 cm tissue covered on one side with mucosa (Fig. 9), traumatic fibroma of the oral mucosa with slightly hyperplastic parakeratotic squamous epithelium with no dysplasia and no significant inflammatory changes, no evidence of fungus in the PAS staining, and no evidence of malignancy.

Fig. 5 Fixation of the tissue to be removed with a surgical forceps during excision of the lesion

Fig. 6 Excision of the lesion from mesial to distal with the activated laser

Fig. 7 Transfer of the excised lesion to a transport container for the histological examination

Fig. 8 Follow-up of the wound 1 week after the procedure. Non-inflamed wound with the expected fibrin coating and no evidence of secondary bleeding
In many cases, treatment methods based on laser technology lead to results similar to those that can be achieved with conventional methods. In the case described here, the indication for the use of laser was supported by the patient’s desire for a minimally invasive procedure. In addition, a second procedure for the removal of sutures was avoided, as has already been described for other laser-based surgical interventions. Furthermore, the possibility had to exist of acquiring a tissue sample suitable for histological evaluation to allow a diagnosis of the lesion to be confirmed. This requirement was also complied with through the use of the 445-nm laser. However, it should be taken into consideration that excessively high power settings can possibly lead to pronounced carbonization of the tissue margins, which would make a histological evaluation more difficult.

From the practitioner’s viewpoint, it can be stated that the fiber tips of conventional diode laser systems (810 to 980 nm) must be conditioned in order to cut effectively. For this, the fiber tip needs to be blackened before treatment to generate more heat at the tip. In addition, direct contact with the tissue is needed for cutting. When the 445-nm system was used, neither of these prerequisites was necessary. Even without direct contact with the surface of the tissue, cutting performance was considerable at a distance of approximately 1 mm.
REFERENCES
