# The Right Wavelength– Areas of application and indications for different kinds of laser

*An interview with Prof Dr Norbert Gutknecht*

Prof Dr Norbert Gutknecht

_Lasers have been used in dentistry since 1964. The idea was to permit treatment of mucosa, hard tooth tissue and bone without involving contact, vibration or pain. They have been increasingly used in various areas of application since the early 1990s. The president of the World Federation for Laser Dentistry (WFLD) and German Society for Laser Dentistry (DGL), Prof Dr Norbert Gutknecht, gives an overview of laser applications that are the subject of controversy, and discusses options for their use in these areas. Every laser has its own special properties, the most significant and fundamentally characteristic one being the wavelength, which defines the position of the laser beam in the electromagnetic spectrum. The interaction of a laser beam with human tissue is essentially due to the energy it delivers into it. The defining factor here is the absorption of the laser beam. Absorption spectra can be visualized for tissue and its components on each wavelength. Besides absorption, reflection and transmission play a role.

**_Professor Gutknecht, let's start with endodontics. What wavelengths are used here?**

The use of lasers in endodontics is aimed at reducing the germs in the root canal, especially in the lateral dentinal tubules (necrotic, gangrenous pulp in the corona and root). We therefore need a wavelength that has high transmission through hydroxyapatite and water. The absorption curves show that with first priority the Nd:YAG laser, to be precise the pulsed Nd:YAG laser, is an option here. It has shown the best results in measurements of transmission and the reduction of germs. Even at a depth of penetration exceeding 1,000 µm, an approximately 85 per cent reduction of germs is still achieved. Going down from there, the second priority would be the diode laser, with a wavelength of 810 nm. Microbiological research has shown that it achieves the second highest reduction of germs. At approximately 63 per cent, however, this reduction puts it significantly below the Nd:YAG laser. Then, below that, we have the 980 nm diode laser. Due to its increased absorption in water, it does not possess a high transmission value. At the same depth of 1,000 µm, it only manages to reduce germs by between 30 and 40 per cent.

None of the other wavelengths, such as those of the Er:YAG, Er,Cr:YSGG or $CO_2$ lasers, plays any role in this treatment. Their absorption in hydroxyapatite and water is so high that a reduction in germs takes place mostly in the main canal. As a thermal effect, a reduction of germs in the lateral dentinal tubules can still be detected to a depth of 300 to 400 µm. So these wavelengths are not very suitable for treating endodontic problems. Er:YAG and Er,Cr:YSGG lasers can, however, be used for removing organic tissue and smear layers.

**_In periodontology we distinguish between closed curettage with a probing depth of 5 to 6 mm and open curettage at probing depths of over 6 mm. What wavelengths are appropriate in periodontology?**

If we want to perform closed curettage with laser assistance in cases of periodontal disease, we can reduce germs with the laser after completing pretreatment and removing the concrement by the conventional method. In closed curettage, we can only use wavelengths whose interaction does not destroy the adjacent hard tissue but which, on the other hand, have good interaction with the soft tissue within the germ spectrum existing in the periodontal pocket. Here, the pulsed Nd:YAG laser can both destroy the germs accumulating on the surface of the hard tissue and—because it couples with pigmented surfaces— tremendously reduce the germs in the pocket. 96 per cent of the germs that are found in the periodontal pocket are pigmented and can thus be selectively destroyed by the laser. Direct coupling with the soft tissue is comparatively gentle, ie, it does not involve a substantial removal of tissue. This permits a relatively conservative procedure and is also associated with really rapid healing of the wound. With the Nd:YAG laser, anesthesia is required in fewer than 50 per cent of cases.

An alternative in this area would be the 810 nm diode laser, whose light has very good coupling with pigmented tissue, so it, too, effects a very high reduction of germs and one can regard it as a match for the Nd:YAG laser. Its coupling with the existing soft tissue is greater, as is its removal of tissue, and it also evolves more heat, so anesthesia cannot be dispensed with during treatment.

The 980 nm diode laser can also be considered in laser-assisted closed curettage. At this wavelength, high coupling with water in the periodontal pocket brings about a similarly high reduction of germs, but at the same time the thermal effect on the tissue is greater because of lower coupling with hemoglobin. This in turn means that we may generate surface necroses if we do not work with extreme care at this wavelength. On this wavelength, too, the temperatures reached are relatively high and anesthesia is necessary.

In laser-assisted open curettage we have a clear, unambiguous application for the Er:YAG laser and, to some extent, where there are special indications, also for the $CO_2$ laser (10.6 µm; cw = continuous wave). The device of choice in support of treatment with open curettage is the Er:YAG laser. It is especially suitable if we can vary pulse lengths and repetition rates very widely. This allows us to carry out extremely good interradicular and interdental cleaning, and the bone tissue can also be very efficiently freed from infected soft tissue. We can moreover generate a really fine retentive pattern on the root and bone surfaces, which is of the greatest significance for reattachment.

**_What pulse length is recommended for use with open curettage?**

If the surgeon giving treatment has the option of varying the pulse length of an Er:YAG laser, short pulses of 60 to 120 µs are ideal. With this pulse length, thermal stress is extremely low so thermal damage to the hard tissue need not be anticipated at all. There is a positive tendency to bleed postoperatively, so wound healing is unproblematic.

The Er,Cr:YSGG laser falls into the category of erbium lasers, which can be used in open curettage. It must, however, be remembered that its absorption in water is two orders of magnitude lower than that of the Er:YAG laser. This means that, if the operation is not carried out correctly, the thermal effect on the tissue will be very much greater.

**_Lasers are also being increasingly employed in implant dentistry. What wavelengths are used when uncovering implants, for example?**

There are several options for uncovering implants, using various wavelengths. The first wavelength ever used for uncovering implants was that of the $CO_2$ laser, 10.6 µm – with the slight disadvantage that this carbonizes the tissue surfaces. The 810 nm and 980 nm diode lasers can be used as alternatives. The area of thermal damage is however larger than with a $CO_2$ laser. Very good results can be achieved with Er:YAG lasers when uncovering implants if the pulse length can be varied or special tips can be used. With pulse lengths of 800 to 1,000 µs, there is an interaction with tissue with a greater thermal effect. This means we can seal smaller vessels without having to leave carbonized or necrotized areas of tissue behind. On the other hand, of course, in the larger vessels we have as always a slight bleeding tendency, which however means that, in comparison with diode and $CO_2$ lasers, wound healing is accelerated, postoperative swelling is reduced, and the wound area heals up with less inflammation. In terms of wound healing physiology, this makes the long-pulse Er:YAG laser an ideal instrument for uncovering implants. With $CO_2$, Er:YAG and Er,Cr:YSGG lasers, no damage at all is done to implants because these wavelengths have a high reflection potential and thus there is hardly any absorption on the metal surfaces. Pulsed Nd:YAG lasers are unsuitable for uncovering implants.

**_What wavelengths should be used in treating periimplantitis?**

The treatment of periimplantitis is performed similarly to closed or open curettage. Both the diode and the Nd:YAG lasers have their areas of indication. Most studies of the treatment of periimplantitis with diode lasers are based on 810 nm diode lasers.

The best procedure for the treatment of a large periimplantitis defect is however to uncover the implant that has been altered by inflammation. Only under visibility can the granulation tissue and the infected tissue be completely removed—above all, only in that way can the infected tissue in the convolutions/spirals of the implant be reached. In this process, treatment with a short-pulse Er:YAG laser is ideal. The shorter the pulses, the more efficiently the granulation tissue can be removed and the less problematic it is to clean the implant surface. Pulse lengths between 60 and 200 µs and very low energy settings make it possible to clear away the infected tissue thoroughly. Similarly good results are achieved with the Er,Cr: YSGG laser.

**_What needs to be observed in soft-tissue surgery, and what wavelengths do you use in this area of application?**

For cutting soft tissue, eg, when incising an abscess, where a sterile cut with as little bleeding as possible is required, the 810 nm and 980 nm diode lasers and the pulsed Nd:YAG laser can be used.

One has to be much more cautious when performing surgery on soft tissue. In frenectomy (operations on the frenula of the lips, cheeks or tongue), the 810 nm diode laser and $CO_2$ laser are very suitable. The Nd:YAG laser and 980 nm diode laser should be used with great caution because the stronger thermal effect of this wavelength (< 100 µs) very often causes necroses.

If very long pulse lengths (> 700 µs) can be set, Er:YAG lasers, too, are again suitable for frenectomy and for soft-tissue surgery in general. The Er,Cr:YSGG laser should also be mentioned, and finally the classic Er:YAG laser, but only with special surgical tips.

**_Could you please explain the difference between a $CO_2$ laser and a long-pulse Er:YAG laser?**

The difference is their absorption coefficients. The Er:YAG laser is very much more strongly absorbed in water, ie, by its interaction with water alone it separates soft tissue in the cells without a strong thermal effect being required. Microscopic ruptures are caused and these lead to increased bleeding. The $CO_2$ laser, by contrast, has very high absorption on the tissue surface. Because of its different mode of operation—in most cases it is a continuous-wave laser—there is greater thermal stress at the surface and not in the depths of the tissue. It therefore leaves carbonized surfaces, but on the other hand there is less tendency to bleed. A positive compromise can be achieved with the long-pulse Er:YAG laser because the very long pulses give a larger thermal component and small vessels are thereby sealed. There is thus less tendency to bleed, but it is not totally prevented, and this in turn means more rapid healing.

**_A provocative question: Is depth of penetration something dangerous? What is your assessment of the depth of penetration of a laser in different types of tissue?**

Precisely in medicine and dentistry, of course, the subject of depth of penetration is highly important. It would be wrong to generalize when evaluating depth of penetration, it always has to be considered in conjunction with the relevant wavelength and the tissue to be operated on. One normally tries as far as possible to minimize the depth of penetration by matching the wavelength to the tissue. There is only one exceptional case in which transmission is desired. Precisely in the case of infected hard tissue in the root canal, or infected bone material, a reduction of germs will also be required in the deeper layers. In addition, it must be ensured that as much of the laser light as possible is absorbed by the tissue. The greater the depth of penetration, the less easily one can control the thermal effects in deeper layers of tissue and the sooner necroses occur.

**_What affects the depth of penetration of a laser into soft tissue?**

The widespread and very frequently discussed notion that Nd:YAG lasers have the greatest depths of penetration into soft tissue is correct only under certain conditions. It is true that the Nd:YAG laser would have an extremely high depth of penetration if one were using a standard industrial laser, which has a continuous-wave mode of operation and emits its power by a non-contact mode. The Nd:YAG laser systems provided by the various manufacturers for use in dentistry are free-running pulsed Nd:YAG lasers. Their pulse width is between 90 and 150 µs, and their energy is delivered through a fiber in contact mode directly into or onto the tissue. Because of the high energy density, there is a very rapid change in the surface of the hard tissue. The depth of penetration is thereby significantly reduced. Professor Joel White at the University of California, San Francisco (UCSF) has made a very graphic study of this point. At the RWTH in Aachen, we have been able to show in a study that a free-running pulsed Nd:YAG laser has a depth of penetration of approximately 0.1 to 0.3 mm, whereas a continuously running Nd:YAG laser has a depth of penetration of up to 6 mm.

**_The repetition rate and pulse length of a diode laser are specific to different areas of application. What precise significance do these settings have?**

Because of its basic physical construction, a standard diode laser emits a continuous laser beam and is thus a continuous-wave laser. With a diode laser, when we speak of pulsing we really mean chopping, ie, interrupting the laser beam. This can be done by switching it on and off electronically. But this is not equivalent to a pulsed laser as the term is normally understood, which outputs high-peak power with individual pulses that can reach several thousand watts. If we want to have pulsed diode lasers with low average power, total power falls. In order to achieve an adequate result on the tissue, one would have to increase the power again without reaching the peak pulse power of the Nd:YAG laser. Attempts are currently being made in many systems to pulse diode lasers electronically so that they have a characteristic similar to that of the Nd:YAG laser, or at least to achieve a free-running pulsed laser system.

**_Should cooling with a water spray be used during treatment with a diode laser?**

There is no comparative research on this point. From a biophysical point of view, however, one must say that the use of a water spray would be counterproductive because water is a good thermal conductor and carries heat away, whereas we want to achieve a thermal effect. Cooling the surface of the tissue is also associated with the danger of inducing a necrosis in deep tissue. Water sprays should therefore not be used with a diode laser.

**_Let's turn to the subject of the literature and further training: What academic sources are serious and trustworthy for laser dentistry?**

There are quite classical standards for classifying academic literature. The most trustworthy literature is review literature. The journals listed in the various indices, eg, Citation Index and MedLine (PubMed), are highly respected academically. Journals that have an impact are quoted and may be quoted over and over again. There are really only three journals that meet these criteria, in my opinion. They are "Lasers in Medicine and Surgery", "Lasers in Medical Science" and the "Journal of Clinical Laser Medicine and Surgery". These are respected academic journals with impact. Where the literature on lasers is concerned, this kind of journal does not exist in Germany.

**_What is the relationship between the German Society for Laser Dentistry (DGL) and the German Society for Dental, Oral and Mandibular Medicine (DGZMK)?**

The DGL is the first laser society to have been incorporated into its national parent dentistry society, the DGZMK. Here in Germany, the DGZMK is the parent society under whose umbrella many other specialist societies are associated. A condition for such an association is clear scientific rigor and an orientation toward clinical practice. The DGL meets these criteria, which is why it is the only society in Germany at the present time that represents our special field and is also legally entitled to represent it.

**_A question for you as president of the World Federation for Laser Dentistry—WFLD: is there a defined "state of the art" for laser dentistry?**

There are of course many "state of the art" assertions, the only question is what they are based on. The objective of the WFLD, and also my personal wish, is actually to get all dental laser societies around one table, to examine for scientific rigor and content all the published standards and education models that have so far appeared.

**_The World Federation for Laser Dentistry (WFLD), is holding its next World Congress from March 2–4, 2010 in Dubai. What is the importance of the WFLD Congress?**

It is a great honor for the WFLD to be integrated in one of the most outstanding dental exhibitions and conferences worldwide, the AEEDC in Dubai. The 2010 Congress is offering an extensive program, from presentations of the latest state of the art, accompanied by brief papers by young scientists, practical workshops dealing with interesting therapeutic questions, and exhibitions by laser system manufacturers who will be providing information about the latest technological advances in laser treatment. So any dental surgeon who is interested can obtain an objective and comprehensive overview of the spectrum of laser dentistry at this Congress.

**_You mention options for further training. What academic training is recognized for laser dentistry?**

A society, no matter what its level, whether national or even worldwide, can neither point the way ahead for training nor provide an academic education. Training courses provided by societies are not academically recognized. A training course, eg, one run by the DGL ("The Specialist") is merely evidence for the participant and documentation for others that he is very strongly concerned with this subject, and the society produces this evidence for him by setting an examination. In academic terms, this certificate has no significance. Thus, if we want to have a specialist, that is, a specialized dental surgeon, that person must get an academic degree. So only university degrees are recognized. It is for the universities alone to acknowledge a given level of education. Training, workshops, seminars or the like that are organized by companies are of course justified. It is frequently the case, however, that training courses developed by firms are mainly beneficial to their own interests. Anyone making out a certificate must prove his entitlement and his ability to provide an education. A university can award diplomas for courses and training units that are carried out at the university or by academic personnel of the university. They have to keep to very special guidelines. It would take too much space to list here all the guidelines that are associated with the award of a certificate.

**_This brings up the question of protection against lasers. What institutions are entitled to train someone correctly as a laser safety officer (LSO)?**

The matter of persons responsible for laser protection is still one of the most controversial questions all around the world. Some countries do not provide any training for such a post. I personally, as a university lecturer and as the president of the WFLD, find it irresponsible for lasers to be supplied or provided without their operators having to show evidence of having passed such an examination. It is moreover a deception to offer courses in laser protection that do not meet the curriculum prescribed by law. Training as a person responsible for laser protection should be given only in certified institutions. The law prescribes a training course lasting at least one day, but in many cases one-and-a-half days, in technical safety and biophysics alone.

**_What would you regard as the ideal training for a dental surgeon who would like to call himself a dental surgeon instructor?**

In order to be competent to hold the title of a dental surgeon instructor, in my judgment, a dental surgeon must meet very specific preconditions. Unfortunately, time and again I see colleagues taking on the title of a dental surgeon instructor, or even being given this title by manufacturers or marketing companies, while they have only a rudimentary knowledge of laser dentistry. A dental surgeon instructor should know not just the basics but should have solid training in the field of lasers. He should have sufficient practical experience in order to present and demonstrate this new technology to his colleagues with real authority. A dental surgeon instructor needs to have far more than just a vague idea of the name of the device and its manufacturer. Anyone who wishes to train dental surgeons should, in my opinion, have the courage to follow the appropriate training. This will give him an objective insight into laser technology at the greatest variety of wavelengths and into the greatest variety of indications for those different wavelengths.

**_In view of the large number of dental lasers on the market, how important do you consider it for field staff also to have specialist training?**

Unfortunately, it is only in a tiny minority of cases that correct information is available to the dental surgeon. This leads many of our colleagues either to view these systems negatively, or to allow themselves to be persuaded because they think the laser will quickly compensate for specific gaps in their knowledge or capabilities. A technical adviser should undergo serious, solid training in order to learn what kind of product he is dealing with, as well as to learn that there are other lasers and other wavelengths, and that indications have to do not only with the size, shape and color of the device, but also with its wavelength and area of application. These are fundamental prerequisites for providing this technology in the form it deserves.

**_Given the flood of information, how can a dental surgeon filter out the appropriate laser for himself?**

I must answer your question quite openly and honestly: a dental surgeon with no prior knowledge of laser technology is in no position to find the correct laser for himself on the basis of brochures or similar material. In order to be able to make a decision, he should take the effort to visit informational scientific events such as the WFLD Congress in March 2010, the congresses organized by national dental laser societies, or other serious informational events. The technology and the multiplicity of indications are far too great for anyone who has not devoted time to them to know their way around. I would go so far as to say that even people who have already devoted time to them occasionally have difficulties selecting the suitable product for the appropriate therapy. In this field, comprehensive advice is indispensable.

**Professor Gutknecht, thank you for this informative interview._**

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