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Prof. Dr Norbert Gutknecht

25 years of DGL!

Dear DGL members and fans of laser technology,

Be aware: while leafing through this issue of *laser* international magazine of laser dentistry you will encounter indications and laser systems that, 25 years ago, the DGL founding fathers would not even have dreamt of.

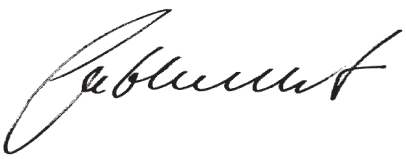
These include blue-light diode lasers in dental surgery, radial firing tips in endodontics, the combination of wavelengths of the near and medium infrared range in periodontology as well as special treatment concepts in paediatric dentistry and modern marketing strategies for adapting laser economically to the dental practice.

When the first DGL Congress was held in Stuttgart/Germany in 1991, speakers and participants only discussed one specific wavelength, the Nd:YAG laser. People were fascinated by the possibility that laser light was transported via quartz fibre to the root canal and periodontal pockets. Those were the days of dental pioneers, going from trial and error to success and failure in quick succession.

The development of laser technology, the discovery of new wavelengths, the establishment of training programmes and the integration in the German Society for Dental and Oral Medicine (DGZMK) prompted the DGL to become today's society for laser dentistry. We now feature high academic standards, distinct treatment concepts for laser application in the dental practice and, most importantly in my opinion, a congress platform which discusses all available laser systems and indications objectively.

For all of the above reasons, I hope you will enjoy both reading our current issue of *laser* international magazine of laser dentistry as well as attending our anniversary congress in Munich.

Yours faithfully,



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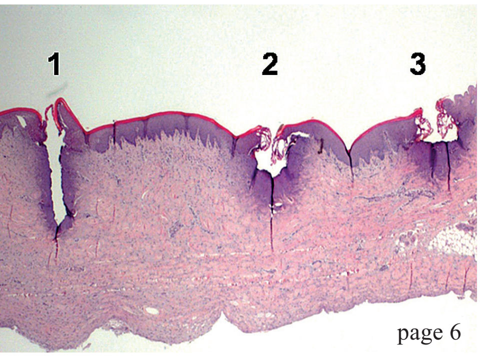

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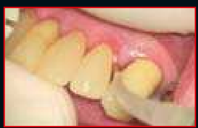

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A novel blue light diode laser (445 nm) for dental application

Biomedical testing and clinical aspects

Authors: Prof. Dr Matthias Frentzen, Dr Dominik Kraus, Dr Joana Reichelt, Dr Christoph Engelbach, Dr Claudia Dehn & PD Dr Jörg Meister, Germany

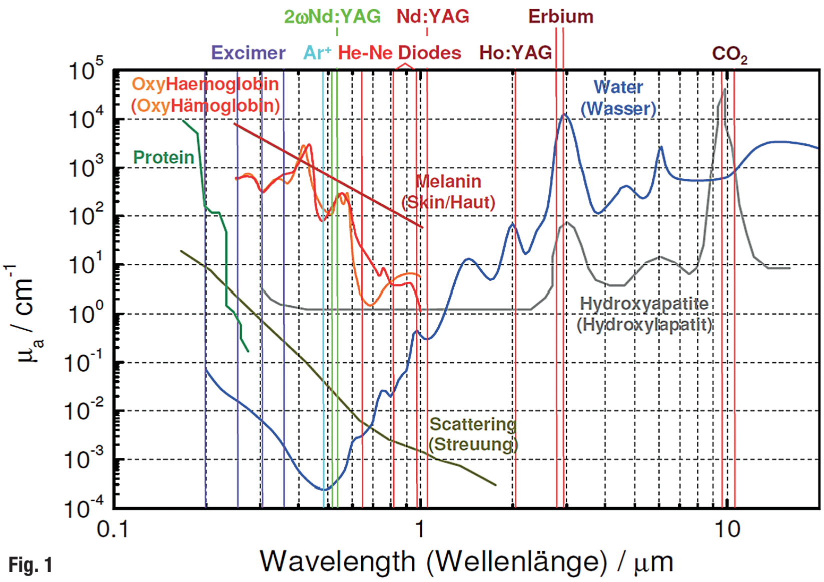


Fig. 1

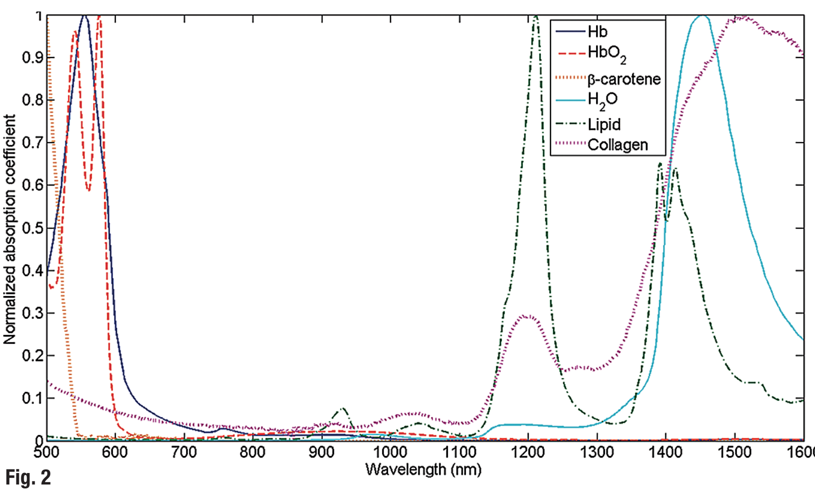


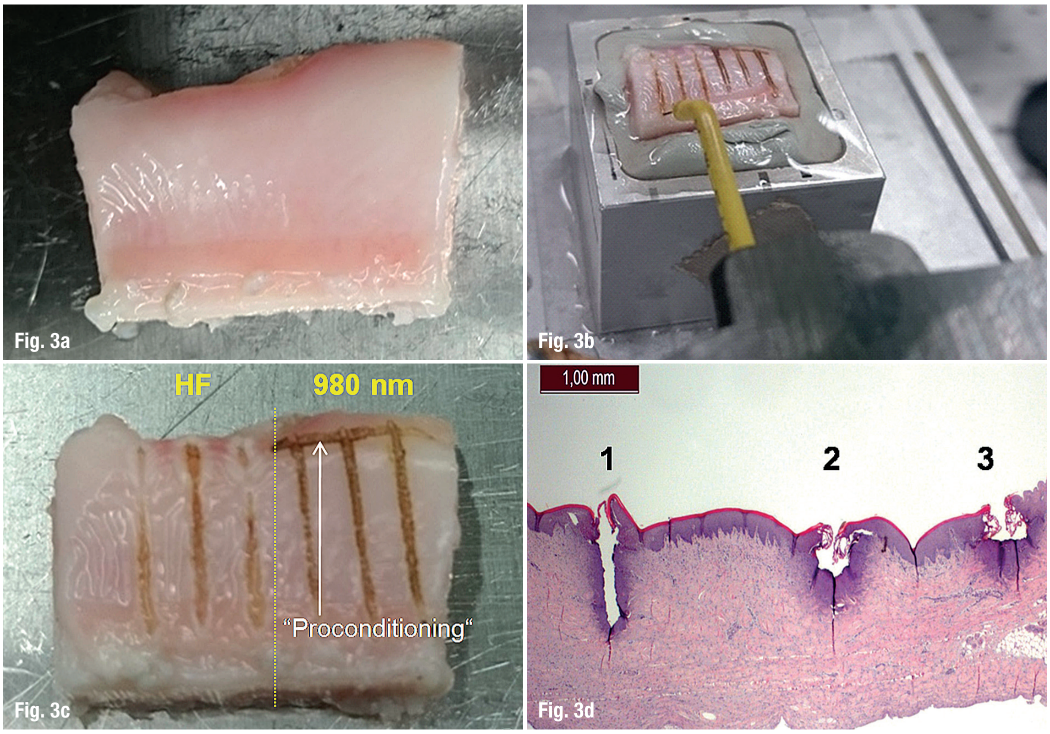
Fig. 2

The 445 nm laser represents an innovative extension to the already established diode laser systems. Improved cutting performance at a lower power level while retaining the advantages of the use of diode lasers for the treatment of oral soft tissue means that this is a further development in addition to the infrared systems with no apparent disadvantages.

Introduction

In the last ten years, diode lasers—primarily in the near infrared spectrum (NIR, 800–1,000 nm)—have become established in dentistry on evidence-based fundamentals for surgical indications.[1] They are used primarily for the cutting and removal of oral soft tissue but also for the disinfection of gingival pockets[2,3] and root canals.[4] From a technical point of view, this technology is not particularly error-prone or expensive compared to gas or solid-state lasers and, when used correctly, the side effects can be easily assessed from the clinician's perspective.[5] The further development of laser diodes has enabled an expanded emission spectrum. As a result, laser application systems that emit in the blue light region are technically feasible nowadays.[6] From a biomedical point of view, these wavelengths provide significant advantages while maintaining an established technology. Blue light is already used clinically in a large number of medical indications.[7,8] As a result of the radiation

Fig. 1: Overview of absorption constants for different biological materials at different wavelengths. – **Fig. 2:** Absorption constants in the range of 500 up to 1,000 nm of soft tissue structures (according to 25).



Figs. 3a–d: Test setup for the implementation of standardised gingiva incisions: **a)** gingiva sample (mandibula, soft tissue and bone/pig); **b)** sample fixed on the optical bench; **c)** example of irradiated sample (HF versus 980 nm, 3 W cw, 5 mm/s); **d)** histological section of Fig. 3c (HE-staining), 1: HF surgery, 2 & 3: laser 980 nm, 3 W, cw.

output available up to now, surgical applications of the blue light lasers have not yet been realised to a significant extent. However, approaches to this have already been available in literature for a number of years.[6,9]

The modification of diode laser technology in dentistry towards systems with emission in the blue light spectrum can open a large number of advantages in comparison to the established diode laser technology in the NIR as a result of the biophysical properties. This includes, among others, a huge working effectiveness at considerably lower power settings. Because of this, for instance the side effects can be reduced considerably. Furthermore, there is a favourable effect on wound healing.[10] Antimicrobial effects are highly exceeded in comparison with infrared radiation and promote an effective disinfection of contaminated tissue areas.[11-13] In this way, the blue light may prevent wound infections. Clinical experience with radiation in the region of 450 nm is already available in many disciplines of medicine without any disadvantages of these wavelengths.[14-16]

Biophysical properties of 445 nm laser radiation

The possible use of a laser application system with an emission wavelength of 445 nm for surgical procedures on oral soft tissues (incision/excision as well as bacterial decontamination and haemostasis) requires a high level of absorption of the radiation used in these tissues to work effectively. These are primarily well perfused gingival tissues of the oral mucosa including the subepithelial connective tissue. Examples are the free gingiva, attached gingiva, alveolar mucosa, buccal mucosa, palatal mucosa, and mucosa of the tongue.

The absorption constant for a wavelength of 445 nm shows a high level of absorption in melanin and haemoglobin (Fig. 1). Furthermore, the absorption in collagen also increases significantly in the wavelength range of blue light (Fig. 2). Absorption in water, however, is lower compared to conventional NIR surgical diode lasers. In addition, scattering in the blue light spectrum also increases (Fig. 1). These biophysical effects mean that, in comparison to the infrared diode lasers, the working effectiveness may be considerably higher at the same power settings as a result of the huge increased absorption in the tissues. With regard to tissue vaporisation, intensive absorption may improve cutting effects. The increased level of absorption in comparison with conventional diode lasers could lead to a reduction of the thermal side effects outside the work area. The specific absorption constants related to blue light are therefore a basis for an effective limiting of biological side effects outside the radiation field.

The absorption of light at 445 nm in water is low. This means that, during surgical procedures, the radiation energy is almost completely transmitted through the non-pigmented mucin layer. Therefore, the cutting procedure starts immediately; there is no need for a so-called initialisation of the incision needed in cases by using diode lasers in the NIR.

The biophysical effects of blue laser radiation therefore favour the effective ablation of tissue from the beginning. Transmission properties and thermographic investigations confirm these observations: Transmission through agar layers of 3 mm thickness is approximately 80 % at 445 nm, independent of the laser power from 100 mW to 1 W for irradiation periods between 5 and 20 seconds. The increase in temperature in this layer cannot be measured when the laser power is 100 mW, with a laser power of 1 W, a temperature increase of $\Delta T = 2\,°C$ could be observed. In contrary, in blood agar, high absorption (> 98 %) and temperatures were measured. The comparison of the biophysical properties of laser radiation between diode lasers with wavelengths of 445 nm and 810–980 nm shows that in both cases photothermal effects are responsible for the laser-tissue interaction. On the basis of the laser settings that are technically possible, no non-linear effects, for example the formation of plasma, are assumed. The different absorption constants, however, support the vaporisation of oral soft tissue at 445 nm in comparison with IR lasers at 810 nm and 980 nm.

In vitro investigations using a 445 nm diode lasers

Preparations from pig jawbones are particularly suitable as a model system for the investigation of the effects after laser irradiation under *in vitro* conditions. The macroscopic structure, the dimensions and the histological structure are very similar to human tissue so that valid statements can be made.[17-22] Gingiva preparations obtained from the vestibular mandibles of freshly slaughtered pigs were used for the investigation of the cutting effectiveness and histologically analysis of side effects during tissue preparation. They consisted of a rectangular segment of bone covered with gingival tissue (Fig. 3a). These samples were stored in physiological saline solution and were fixed to an optical bench immediately after removal (Fig. 3b). This bench was equipped with a linear micro-

Fig. 4

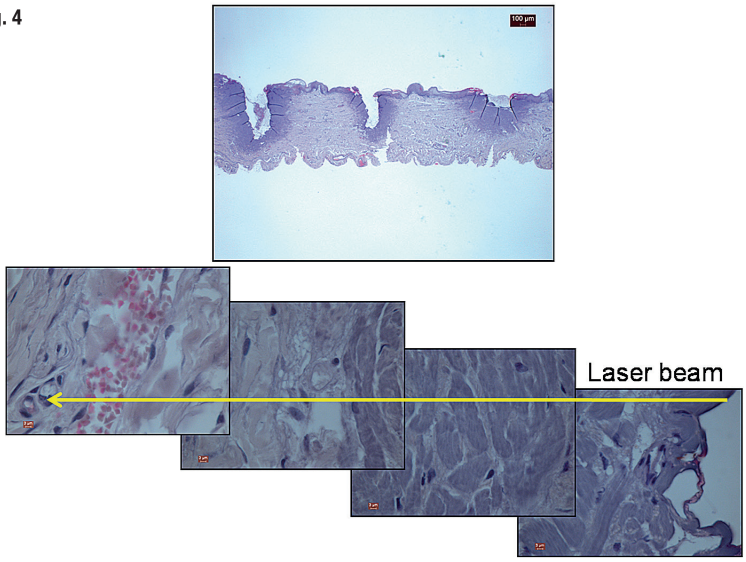


Fig. 5

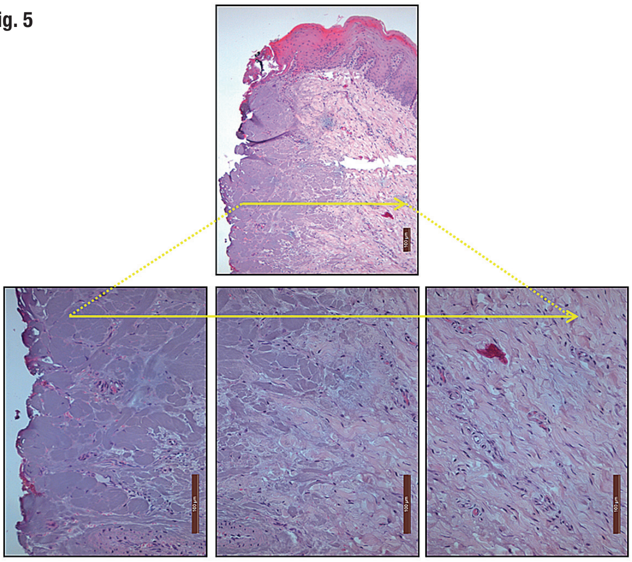


Fig. 6

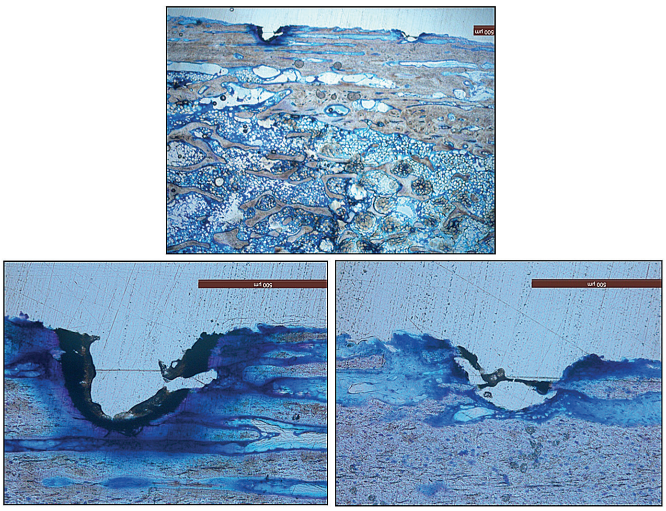
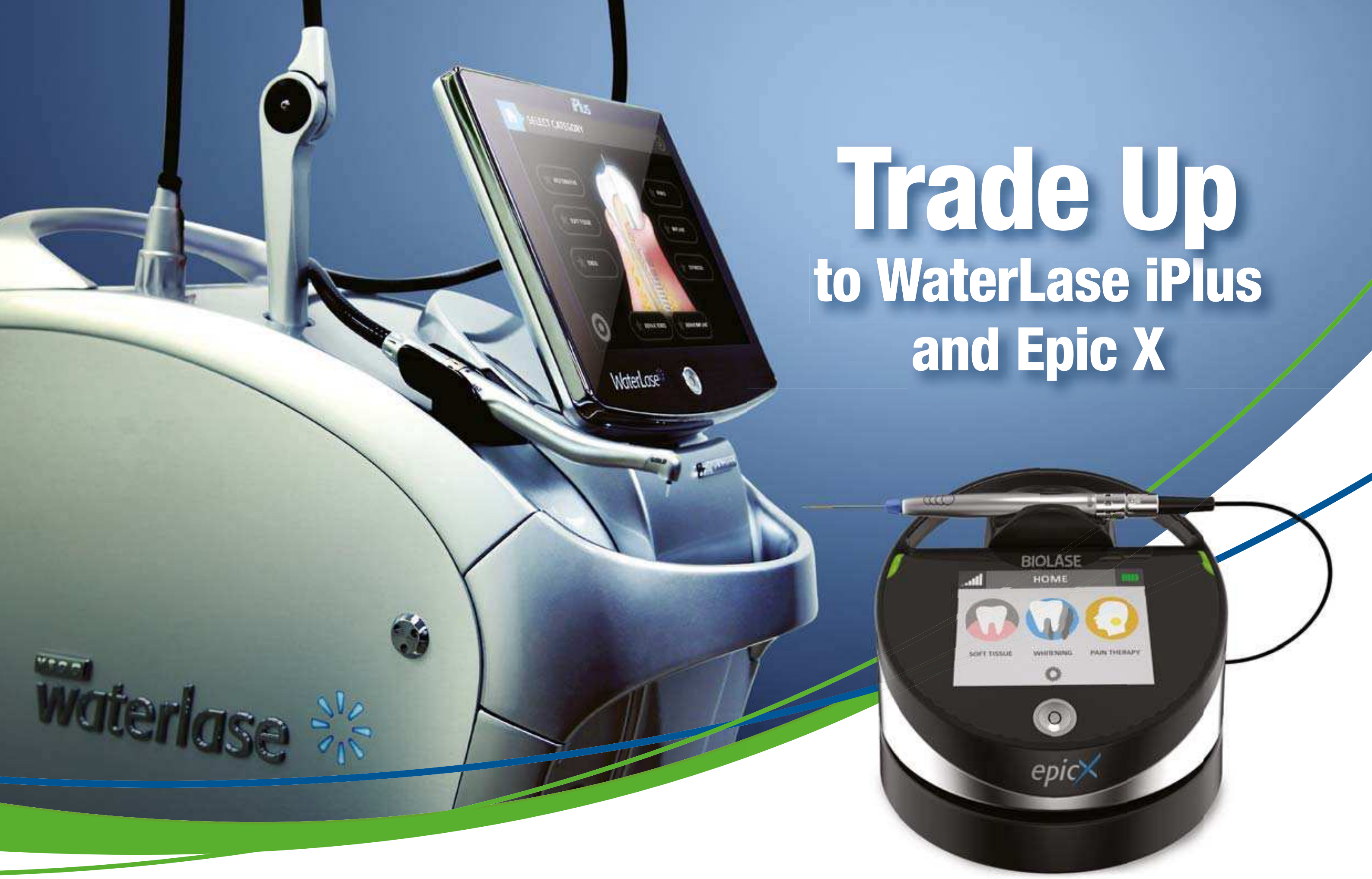


Fig. 4: Ex vivo sample from pig gingiva after 445 nm laser incision (2 W, cw). The high resolution photo collage shows that, starting from the surface, the morphology of the tissue has been preserved with a thin carbonisation film. No vacuolar structures and bleeding into the connecting tissue were detected. The incision edge is covered by a very small carbonisation layer. – **Fig. 5:** Detailed images of the subepithelial connective tissue after incision with 445 nm/2 W, cw. An undermined blistering (tissue destruction) in the area of the lamina propria as is known with the 980 nm is only very slightly pronounced. The micromorphology of the tissue is preserved underneath the cutting level despite increased staining; no tissue haemorrhage was detected. – **Fig. 6:** Histological thin section after irradiation of a pig jawbone specimen using a 980 nm diode laser (2 W, cw, left) and using a 445 nm diode laser (2 W, cw, right), undecalcified thin section, staining: toluidine blue. With 980 nm, wide carbonisation zone with surrounding necrosis; with 445 nm, narrow carbonisation and necrosis zones.



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