Swap Drills for Light Energy

An interdisciplinary collaborative research project

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_The overall aim of prevention-oriented dentistry is to offer (laser) light-based diagnosis and treatment with outstanding capabilities. An example of this is the early detection of hidden carious lesions, which are clinically and radiographically barely detectable, using light-induced fluorescence. Through a combination of photosensitisers and light, bacteria-contaminated gingival pockets can be disinfected. Laser light is even capable of replacing the scalpel, allowing incisions resulting in reduced blood loss and benign alterations of the mucous membrane. These are just a few of the many new possibilities and developments in the clinical diagnosis and treatment of oral and dental disease through laser-based technology.

For 20 years, the Laser in Dentistry working group at the University of Bonn's Dental and Oral Health Centre has collaborated on research, directed by Prof M. Frentzen, and participated in a number of national and international development projects. This includes the collaborative MiLaDi (Minimally Invasive Laser Ablation and Diagnosis of Oral Hard Tissue) project for researching ultra-short pulse laser technology. The Federal Ministry of Education and Research-funded project involves a research collaboration between the Lasers in Dentistry working group and two industrial companies: Sirona Dental Systems GmbH and Lumera Laser GmbH, a medium-sized business with many years of experience in manufacturing ultra-short pulse lasers in science and industrial material machining. The main goal of the MiLaDi project is to develop new laser therapy systems based on ultra-short pulse laser technology through the dental biological and medical research and testing of a laser diagnostic and treatment device with a large range of applications. The project has a total current budget of €6.8 million.

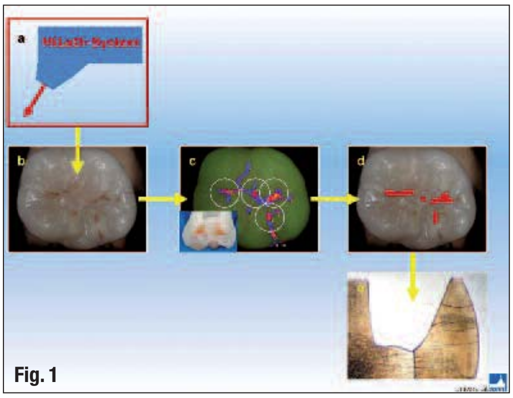

Fig. 1_Selected, fluorescense controlled caries removal.

During the last few years, ultra-short pulse laser has been introduced to fundamental research in dentistry. This technology offers the prospect of treating oral hard and soft tissues efficiently and with minimal damage. The highly precise removal of biological tissues is expected to be associated with reduced pain as well.

The first experience of this technology was in the 1990's with the nanosecond, pulsed excimer laser, which radiated in the ultraviolet area of the spectrum. The newly developed ultra-short pulse laser technology is based on laser devices with wavelengths of around 1 µm (e.g. Nd:YAG lasers), and pulse durations of picoseconds to femtoseconds. Tissue ablation with this type of laser is not based upon the physical principle of absorption, but on non-linear optical effects with changes to plasma generation.

In the near future, short pulse laser therapy should enable users to:

- remove hard tooth substance (enamel, dentine, as well as caries) and mineralised concretions (such as tartar or concrements) in a minimally invasive manner with little or no pain, and allow an objective analysis of the material removed (Fig. 1);
- carefully handle surrounding tissue when treating bone (when performing orthopaedic surgery or implantology, for instance);

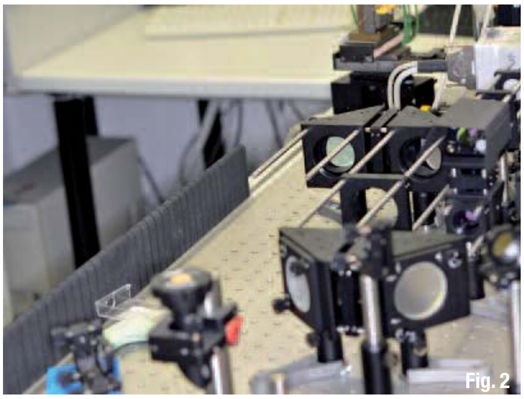

Fig. 2

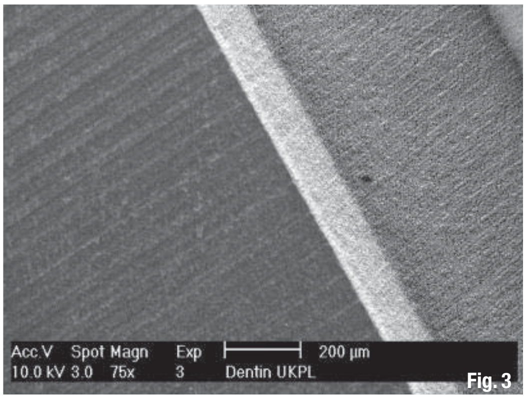

Fig. 3

Fig. 2_Fundamental examination of test samples on an optical bench.
Fig. 3_SEM of a laser drilled cavity.

- perform surgical procedures on healthy and diseased oral soft tissue, and carry out analysis of the material removed;
- perform biofilm management of plaque-associated diseases in the areas of cariology, endodontology and periodontology.

As a part of ongoing research, a fundamental examination is performed to examine the effect of ultra-short pulse radiation on biological tissue and restorative materials (Fig. 2). The detection procedure can then be tested, based on fluorescence and plasma spectroscopy.

To test clinical relevance in the treatment of dental hard tissue, the processing speed of enamel and dentine must be determined. The ablation volume of dentine, without air or spray filling, is approximately 10 mm^3/min. The efficiency seems to improve significantly due to optimisation and in particular due to the scan parameter. Carious dentine can be ablated four times faster than healthy dentine.

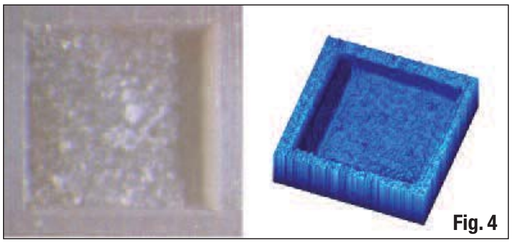

Fig. 4

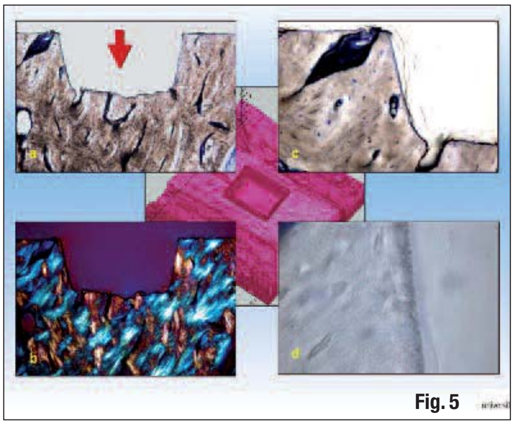

Fig. 5

The cavities do not show any histological indications of thermal damage but a smooth and extremely sharp-edged contour. It seems as though no smear layer forms (Fig. 3). Consequently, it is possible to prepare cavities with laser. In order to ensure a sufficient width of the therapy spectrum with ultra-short pulse laser technology, restorative materials were also tested with this technology to demonstrate the extent to which they could be handled. Clinically relevant ablation rates, by the usual tested materials, indicate the possibility of effective laser treatment of restorative materials (Fig. 4).

The basis for the surgical application of ultra-short pulse laser is the efficient and careful ablation of oral soft and hard tissue. As histological studies demonstrate, bone can be handled without spray and air cooling with no detectable side-effects (Fig. 5). The clinical efficiency is, according to available results, comparable to traditional methods.

The collaborative project is currently focusing on systematic examination relevant to laser parameters, as well as the development of a suitable radiative transfer system, including adequate detection systems. The results achieved so far are very promising and make patient-oriented advancement a possibility._

_contact laser

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Fig. 4_Photomicrograph of laser cavity in composite. The 3-D display of the same cavity appears on the right. The defined edges of the cavity are particularly distinguishable here.
Fig. 5_Histological section of a laser cavity in bone slowing no side-effects.