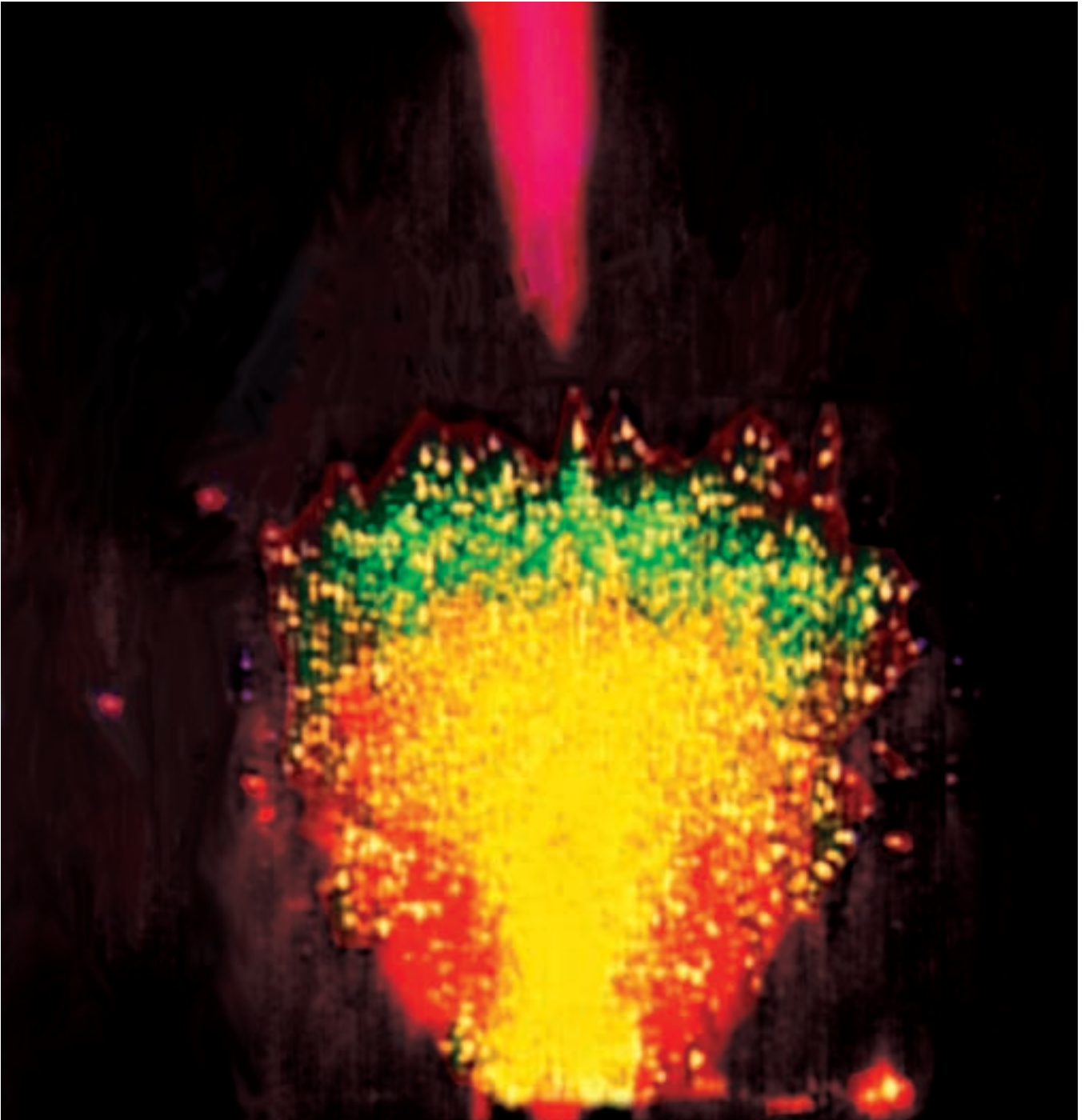




K·E·Y Laser 1242/1243



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Preface

Ever since the implementation of the first laser by Maiman in 1960, various attempts have been made to use the laser in dentistry. For a long time, however, the thermal side effects associated with the lasers operating in the visible wavelength or far infrared ranges prevented widespread use of laser technology in dental applications.

The development of a new solid-state laser, the KEY laser, made accessible a new laser wavelength that has the special characteristic of coinciding with the maximum absorption peak of water. Contrary to other lasers, this high degree of absorption combined with the pulsed operating mode of the KEY laser permits excellent material ablation rates in conjunction with minimal thermal influence.

The idea by Hibst of the ILM (ILM, Institut für Lasertechnologien in der Medizin) and Keller (Ulm university), to employ the KEY laser in dentistry, was adopted by KaVo and resulted in a joint project culminating in the development of a laser ready for use in the dental surgery - the K·E·Y Laser (K·E·Y stands for KaVo erbium YAG).

The KEY laser has been successfully tested in clinics at the universities of Ulm, Erlangen, Würzburg, Frankfurt and Hannover.

This application manual is intended to make available to the practitioner the experience gained by the above-mentioned research institutions.

The K·E·Y Laser is a medical device according to MPG (ordnance governing medical equipment) Class, IIb and the manufacturer is therefore responsible for the safety of the product and compliance with all the relevant regulations regarding design, installation and commissioning of the unit. The decision concerning the suitability of the device, however, the responsibility for proper identification of indications, correct execution of operation and all side effects that may occur rests with the dentist performing the treatment. The elementary course (DE: according to §2 of MPBetreibV, resp. country specific regulations, US: ANSI Z136.1) is intended to support the dentist in this. Participation in this course is included in the purchase of the K·E·Y Laser and also permits the participant to acquire the qualification of a laser safety officer (DE: BGV B2, US: ANSI Z136.1).

The expandable concept of this application manual permits the standard of knowledge to be updated by supplements to be issued periodically. Basic tissue effects are described in Part **A**. Applications are described in Part **B** and corresponding major basic research work is shown in the relevant bibliography. Part **C** contains case descriptions taken from the experiences of practising dentists. Although these individual reports have not been verified statistically or scientifically they are however plausible for reason of the described fundamentals. In addition to these reports, the user is advised to contact colleagues and clinics with the appropriate equipment and to refer to other sources of information, e.g. current literature so as to be able to make careful consideration of the issue.

Information referring to laser parameters and indications corresponds to today's knowledge in leading laser research work and the experience of practising dentists.

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Note on cover picture:

High-speed photography showing dentine removal with the KEY laser.

The ablation process is rendered visible by illumination during the 10ns laser pulses (red, green). The particles are expelled at approx. the speed of sound. Neither plasma nor destructive shock waves are generated (Q [1]).

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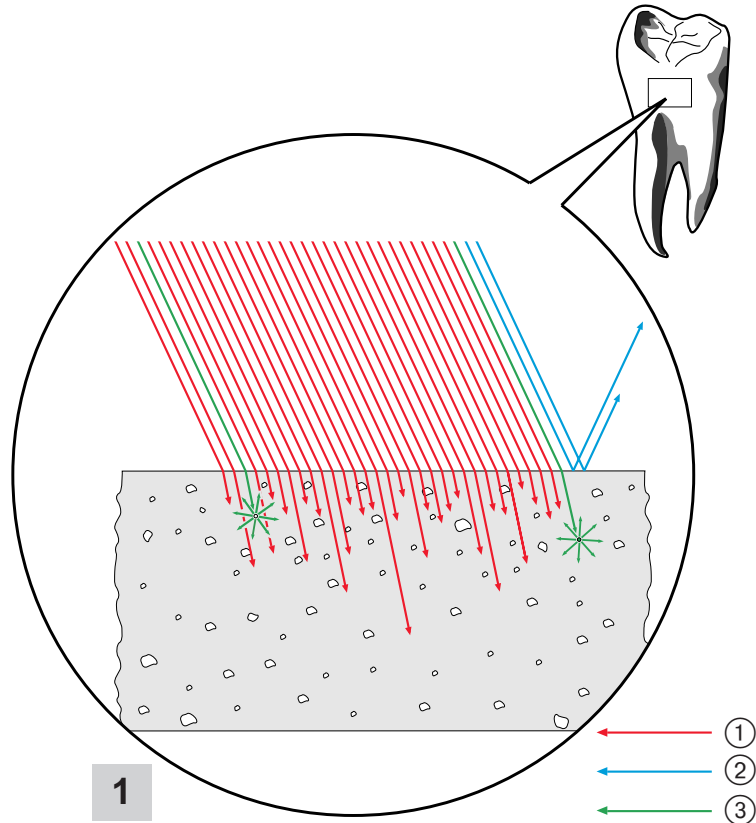
A 1 Physical effect of laser radiation on biological tissue

A 1.1 Optical properties of bodies

The light distribution of optical radiation in a body is determined essentially by the reflection at the surface and the absorption and dispersion in the tissue. Since the absorption of the radiation in body tissue is very high in the case of the KEY laser, the dispersion is negligible.

Fig. 1 shows the absorption, reflection and dispersion in the body tissue.

- ① Light absorbed
- ② Light reflected
- ③ Light scattering

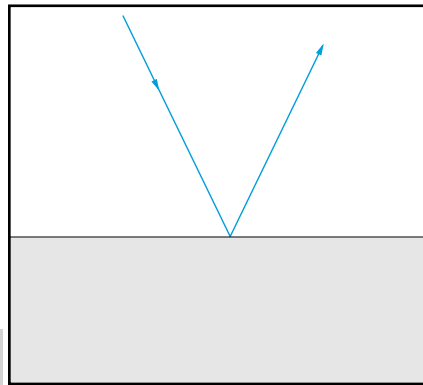


• Reflection

When the laser beam hits the surface of body tissue, a generally small part of the radiation is reflected directly from the surface and remains without any therapeutic effect.

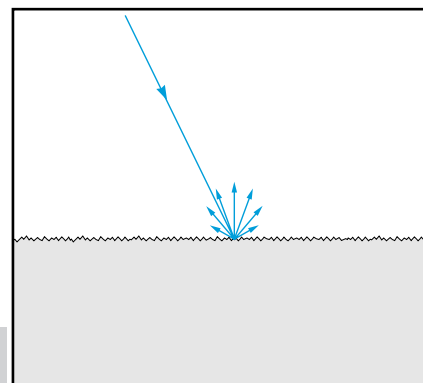
The orientation of the reflection may be direct or diffuse depending on the angle of incidence, difference in refractive index and surface structure (fig. 2.1 shows directed reflection on a reflecting surface).

2.1



If the surface unevenness is great with regard to the wavelength (factor of 2 to 5), the reflection is predominantly diffuse, and the surface appears to be mat (fig. 2.2 shows diffuse reflection on a rough surface).

2.2



A mixture of directed and diffuse reflection will occur in practice and will produce a glossy surface in the visible range (fig. 2.3 shows a mixture of diffuse and directed reflection on a shiny surface).

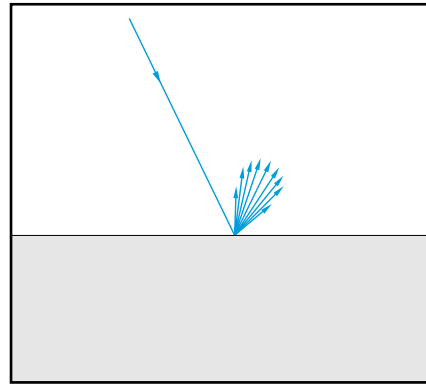
The dependence of the reflection on wavelength is also the reason that a surface appearing mat in the visible range may have a greater portion of directed reflection in the infrared range.

This must be taken into account for the use of surgical instrument sets, hand instruments and mirrors.

In addition to being influenced by surface properties, the degree of reflection of various materials also differs depending on wavelength; this effect is called spectral reflection. Metallic surfaces, such as stainless steel, copper, aluminium, polished amalgam and, particularly, brass, reflect the IR radiation of the KEY laser relatively well. Silver and gold especially are better reflectors in the IR range (with a degree of reflection of up to 99 %) than in the visible range. Ceramic materials are usually less reflective than metals.

Note for application that even black surfaces may reflect rather well in the IR range depending on their surface characteristics.

2.3





Laser beam focusing resulting in hazard due to reflection is generally to be expected only if a convergent beam hits a reflective surface before reaching the focal point (case shown in figure 3a) or if a divergent beam is focused by a concave, reflecting surface (case 3d).

(Fig. 3 shows focusing on reflective surfaces.)

Case a:
Reflective plane surface - convergent beam.
If a beam converges before hitting the surface, its focal point is reflected by the plane surface.

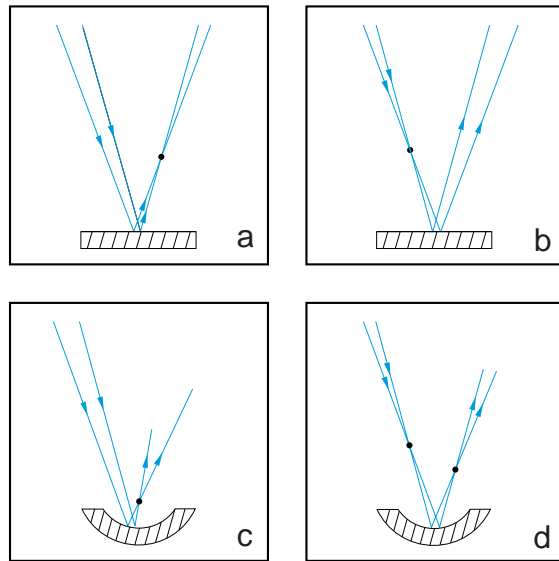
Case b:
Reflective plane surface - divergent beam.
If the focal point is located above the surface, the beam also diverges after being reflected.

Case c:
Reflective concave surface - convergent beam.
The reflective concave surface causes additional focusing of the incident convergent beam.

Case d:
Reflective concave surface - divergent beam.
A beam diverging after the first focal point can be focused a second time if the reflective surface it hits is sufficiently concave.

Because of the high degree of reflection caused by metallic instruments, you should keep the following in mind:

- The size of the focus remains the same in the case of plane surfaces.
- Reflective concave surfaces act like a convex lens.
- Convex surfaces have the same effect as a dispersing lens.



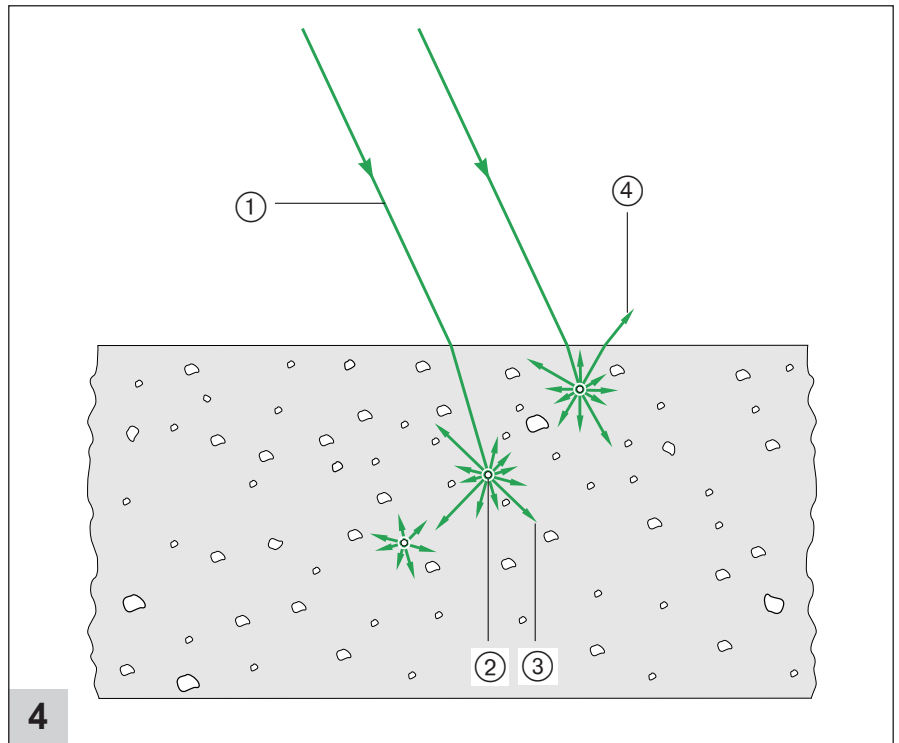
• Dispersion

Light is scattered if it encounters inhomogeneities in a medium. This dispersion is very pronounced in the case of body tissue due to its complex structure.

A portion of the light can be dispersed back from the tissue (re emission). This is noticeable in the visible range when the pilot beam is too bright and therefore illuminates the whole tooth. (Fig. 4 , dispersion in the body.)

- ① Incident beam
- ② Scattering
- ③ Absorption of scattered light
- ④ Re-emission

The depth of penetration of the KEY laser beam in the body tissue is between 1 and 10 μm , i.e. the scattering at 2.94 μm is negligible regarding the impact on the tissue.



4

• Absorption

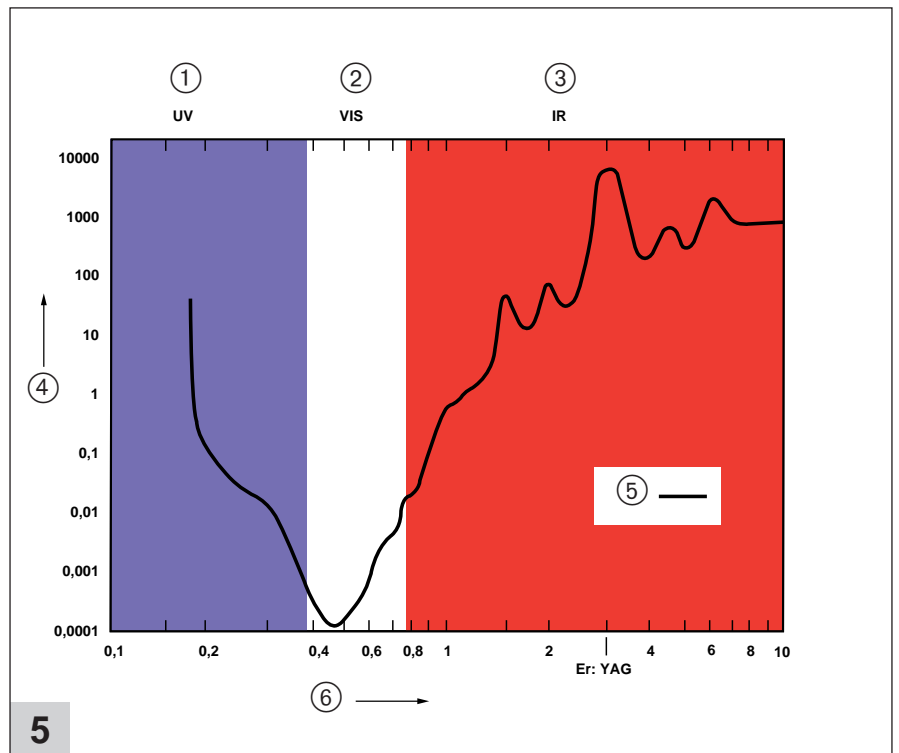
The effect of the laser beam is determined primarily by the absorption properties of the radiated tissue.

The absorption spectrum of water (fig. 5) shows that the wavelength of the KEY laser of 2.94 μm coincides with the maximum absorption in water.

Legend for figure 5

- ① UV = ultraviolet
- ② VIS = visible
- ③ IR = infrared
- ④ Absorption coefficient (cm^{-1})
- ⑤ Absorption coefficient of H_2O (cm^{-1})
- ⑥ Wavelength (μm)

The depth of penetration of the KEY laser beam in water is approx. 1 μm . The absorption spectrum of hydroxylapatite also has a relative maximum at 2.94 μm .



5



The wavelength of the KEY laser is thus predestined for ablation of biological tissue (figures 6 , 7) since this tissue generally contains water. The radiation is absorbed in the outermost surface layers and cannot penetrate into deeper layers of the tissue. Even the low portion of water contained in enamel is sufficient for good absorption. Since the impact point of the focused laser beam is small, the effect of the laser is limited to a small area, thereby minimising heating of the surrounding area.

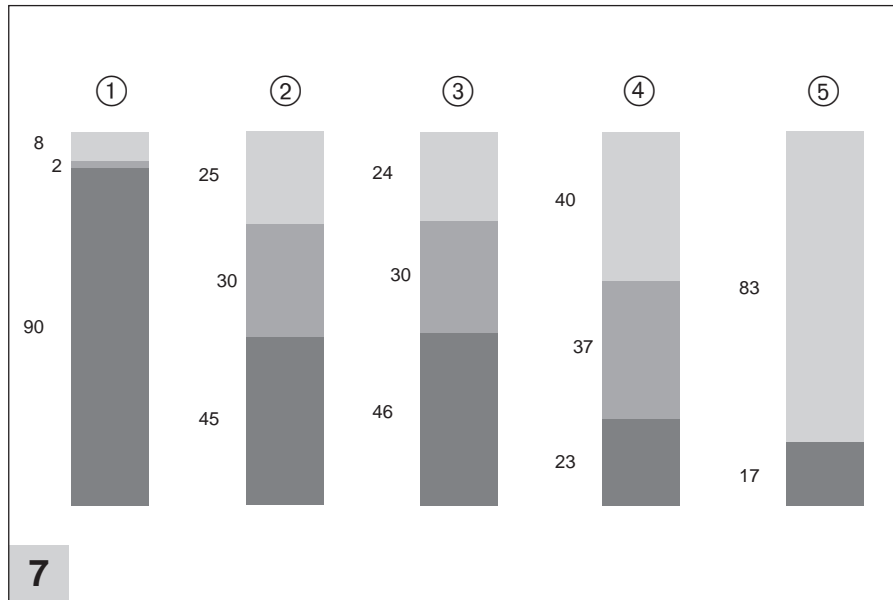
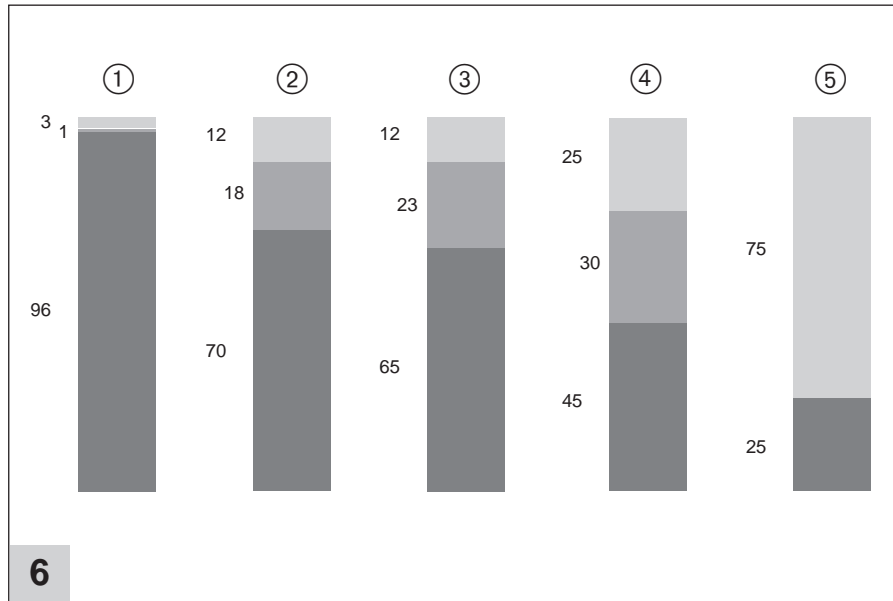
Fig. 6 Portions by weight of water, organic matrix and mineral substance in different dental tissues R [3], R [4].

Fig. 7 Portions by volume of water, organic matrix and mineral substance in different dental tissues R [3], R [4].

- Water
- Organic matrix
- Mineral substance

- ① Enamel
- ② Dentin
- ③ Cement
- ④ Bone
- ⑤ Pulp, gingiva and soft tissue

The KEY laser does not affect genetic information since the absorption lines of the DNA are in the UV range while the KEY laser, with a wavelength of 2.94 μm, emits in the far removed IR range.



A 1.2 Thermo-mechanical ablation

In conventional laser applications, tissue is ablated by evaporation and pyrolysis. This procedure is unsuitable for removal of dental hard substance due to the associated high melting and evaporation temperatures.

Contrary to this, the effect of the KEY laser on biologic tissue is not due to a purely thermal process but is best described as a thermo-mechanical effect on the tissue. It is actually the water contained in the tissue that causes the ablation process due to absorption and permits highly efficient ablation in conjunction with minimal pulse energy requirements. Apart from good absorption, it is mainly the short duration of the K·E·Y Laser pulse that is responsible for its low-strain effect since the exposure to the laser beam lasts just fractions of a thousandth of a second.

Thermo-mechanical ablation takes place due to the fact that the water contained in the tissue is transferred from the liquid to the vapour state very suddenly by absorption of short laser pulses. The resulting rapid expansion of the water very briefly generates a pressure sufficiently high to remove tissue substance in the manner desired.

Another advantage of the KEY laser is that the energy required for ablation is not primarily determined by the evaporation temperature of the tissue substances with a more elevated melting point but by the considerably lower evaporation energy and temperature of water.

Also, only a part of the tissue volume, i.e. the water portion, needs to be evaporated. Therefore another characteristic of the ablation process is that removal only begins when a specific energy density (ablation threshold) is exceeded. This threshold is approximately 3.3J/cm² for enamel, 2.8J/cm² for dentin, 1.3J/cm² for bone and 0.8J/cm² (Bib [103]) for skin. When operating subablatively (below the ablation threshold), the tissue is merely heated up and dehydrated.



Fig. 8 (ablation mechanism) gives a schematic representation of the various zones in the tooth that can be identified with exposure to the laser beam.

Explanations for fig. 8 :

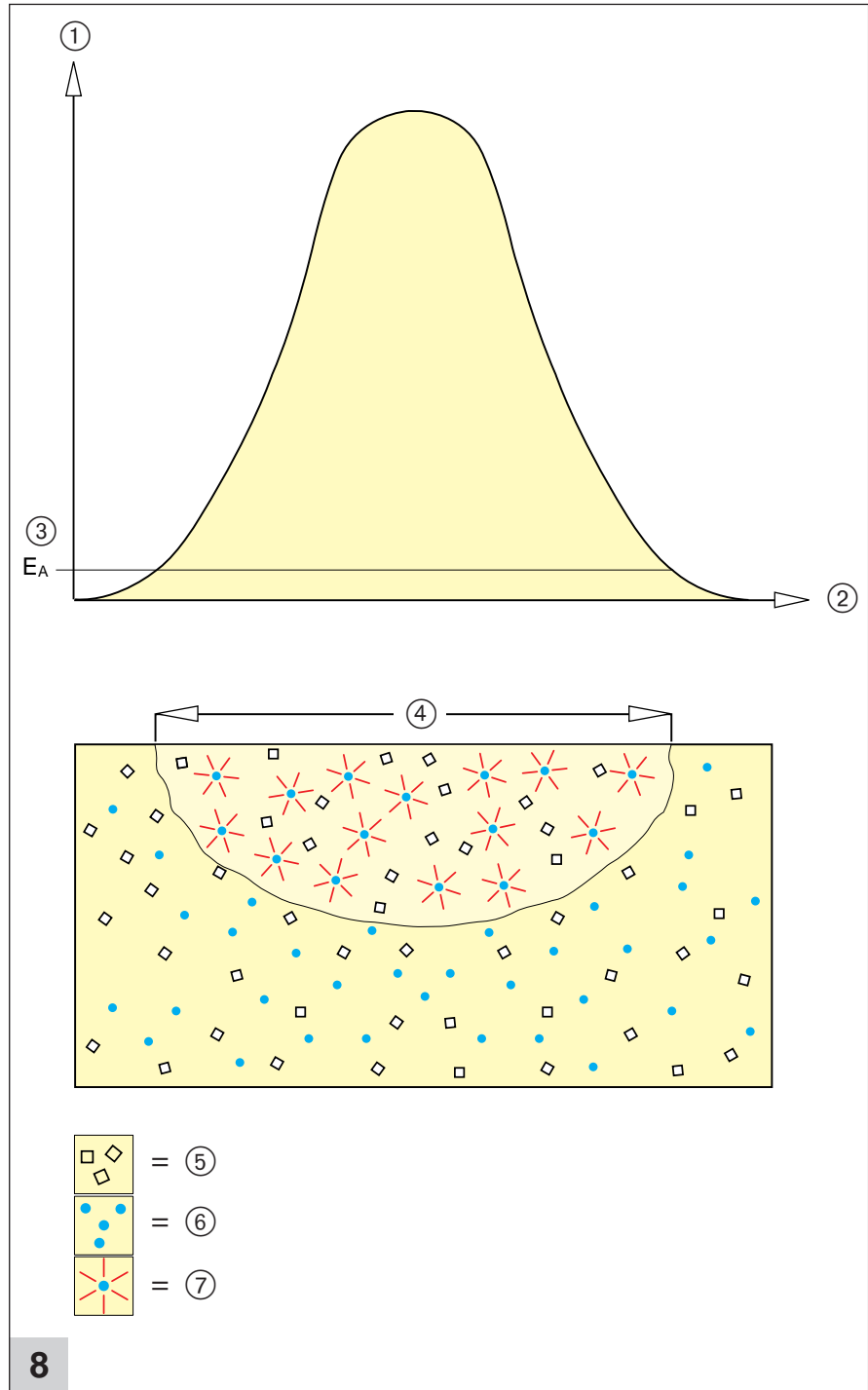
- ① Energy density
- ② Beam diameter
- ③ EA = ablation threshold
- ④ Ablation zone
- ⑤ Mineral portion of tissue (hydroxylapatite, etc.)
- ⑥ Tissue water
- ⑦ Ejection due to water evaporation

Material removal takes place in the ablation zone as soon as the evaporation threshold of the tissue water is exceeded.

When material particles are ejected due to the thermo-mechanical process taking place in the ablation zone, a part of the heat required to initiate the evaporation process is dissipated.

The particles only reach their melting temperature for a very short period and only above the tissue surface. They light up as they fly through the incident beam and cool off as they continue to fly through the air (see photograph on front cover, Bib [34].

The ablation occurs as a continuous process during a laser pulse so that the depth of the resulting crater is a multiple of the laser beam penetration depth.



A 2 Biological effect of laser radiation on various tissues

A 2.1 Dental tissue

• Enamel, dentin

- Morphology

(Bib [4], [29], [50] Scanning electron microscope images of laser operations in dentin and enamel prove the predominantly mechanical effect of the ablation process (see section A 1.2), see figures 9 to 11 for enamel and figures 12 to 14 for dentin (R [5]). The surface roughness in dentin is lower than in enamel. The dentin tubuli are open.

The crater diameter is determined primarily by the beam diameter and the pulse energy.

9 Enamel cavity, 1 pulse, 250 mJ, with spray (magnified 60 times)

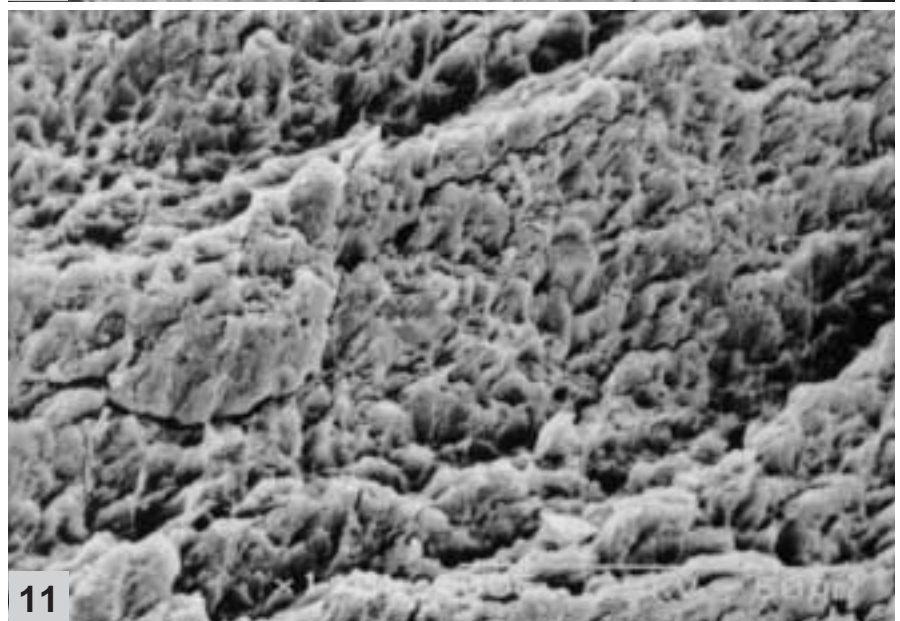
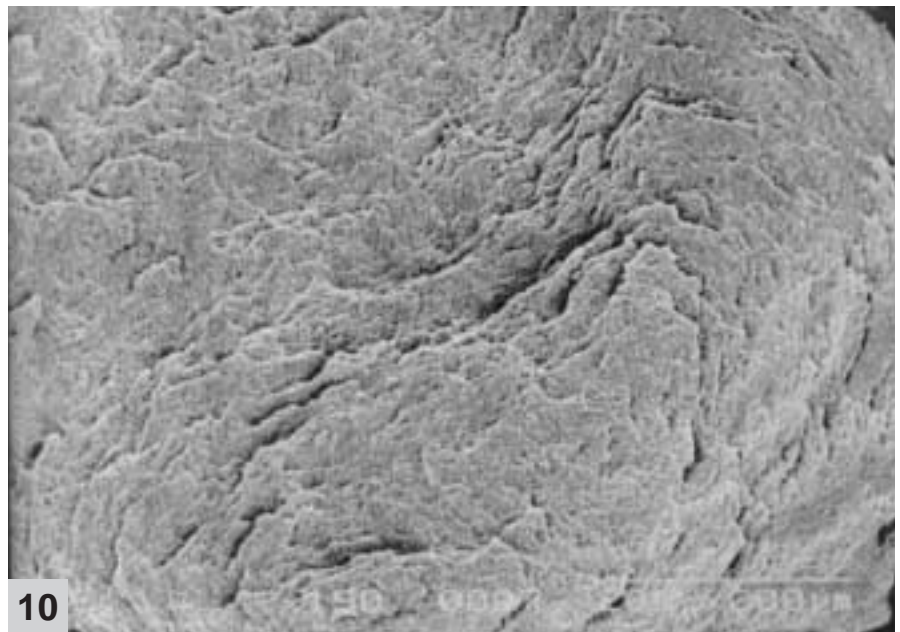
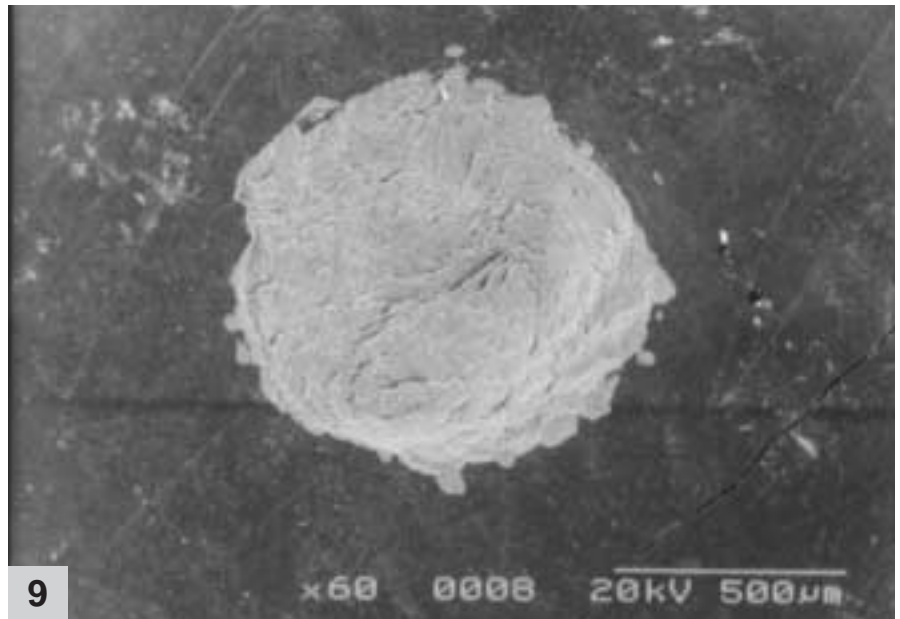
An approximately round crater with a typically plaque-shaped/scaly surface structure can be recognised. The marginal area is irregular in shape. There are no signs of thermally induced cracks.

10 Enamel cavity, 1 pulse, 250 mJ, with spray (magnified 150 times)

The plaque-shaped enamel surface structures show a more or less firm attachment to the base material. There is no evidence of fusion. Fine, relief-like formations can already be observed.

11 Enamel cavity, 1 pulse, 250 mJ, with spray (magnified 1000 times)

Prism centres and periphery show different ablation behaviour. Micro and macro-retentive enamel portions are in evidence.





12 Dentin cavity, 1 pulse, 250 mJ, with spray (magnified 60 times)

A relatively flat cavitation can be seen. The marginal areas are irregular but without evidence of thermal impact. The surroundings of the crater show a homogeneous smear layer.

13 Dentin cavity, 1 pulse, 250 mJ, with spray (magnified 150 times)

Fine, plaque-shaped enamel surface structures show a firm attachment to the dentin base material. Some exposed dental tubuli are discernible.

14 Dentin cavity, 1 pulse, 250 mJ, with spray (magnified 1000 times)

Open dental tubuli show on the fine, plaque-shaped structures. The openings are surrounded by a clearly visible wall of peritubular dentin. Fusions and cracks are not present.

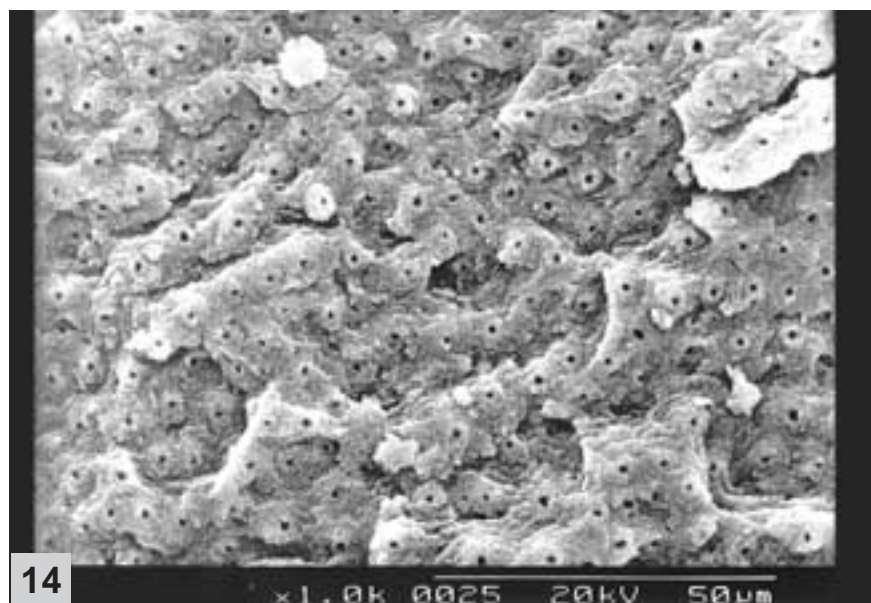
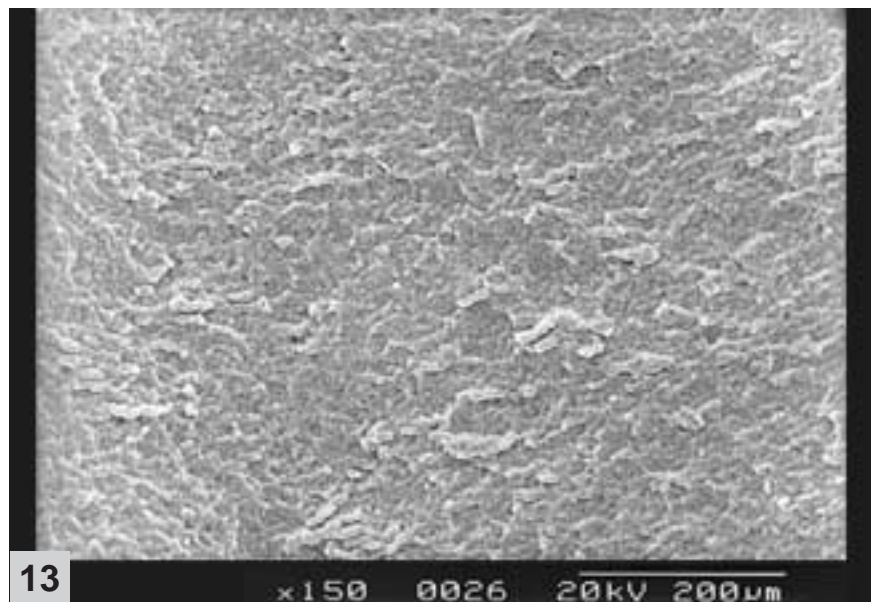
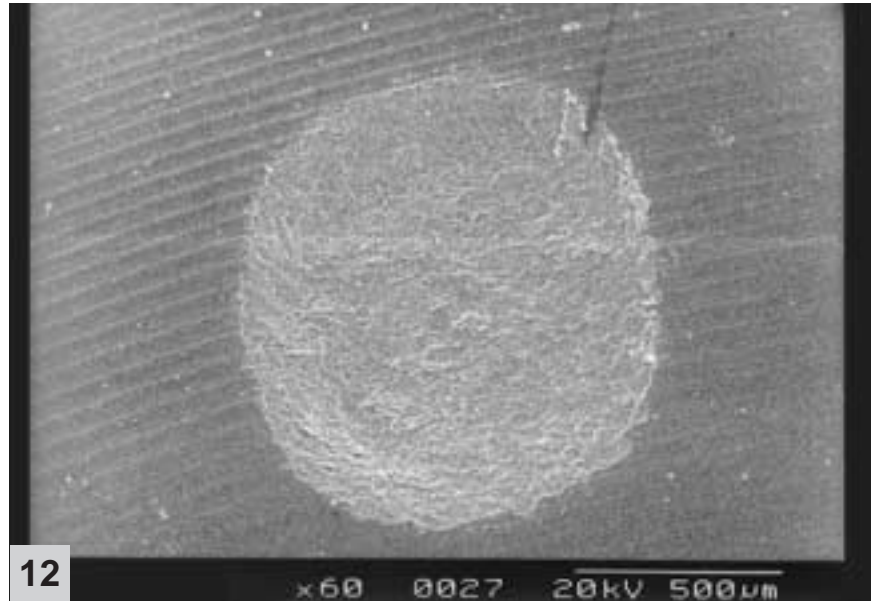
- Efficiency of ablation

The crater depth is linearly dependent on the number of pulses applied to one site.

The relationship between ablation rate and pulse energy is virtually linear for both enamel and dentin, with the efficiency in dentin being approximately twice that in enamel (Bib [3]).

At identical pulse energy levels, the craters in dentin are somewhat larger in diameter than in enamel.

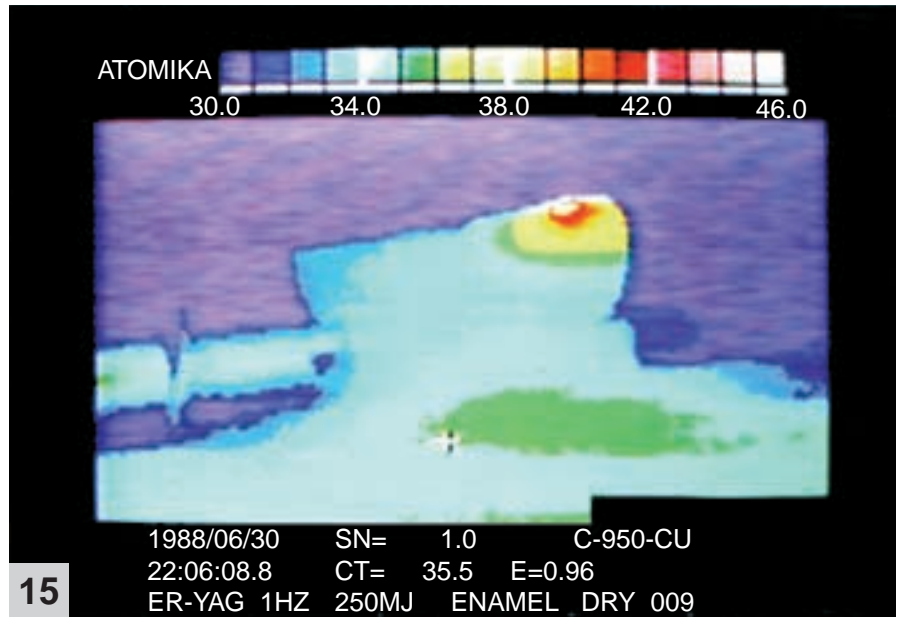
When operating below the ablation threshold without spray or with excessively low pulse energies, the ablation process may cease, for example, in thick enamel layers, because of tissue dehydration.



- Temperature

Temperature measurements employing a thermocouple in the perforation test. Surface temperature measurements with a video thermo-camera system (Bib [7], [30] and intrapulpal in-vitro temperature measurements (Bib [20]) furnish proof of the minimal thermal effect of the ablation process caused by the KEY laser beam. It was also possible to prove the efficiency of spray cooling (Bib [31], [78], [88]).

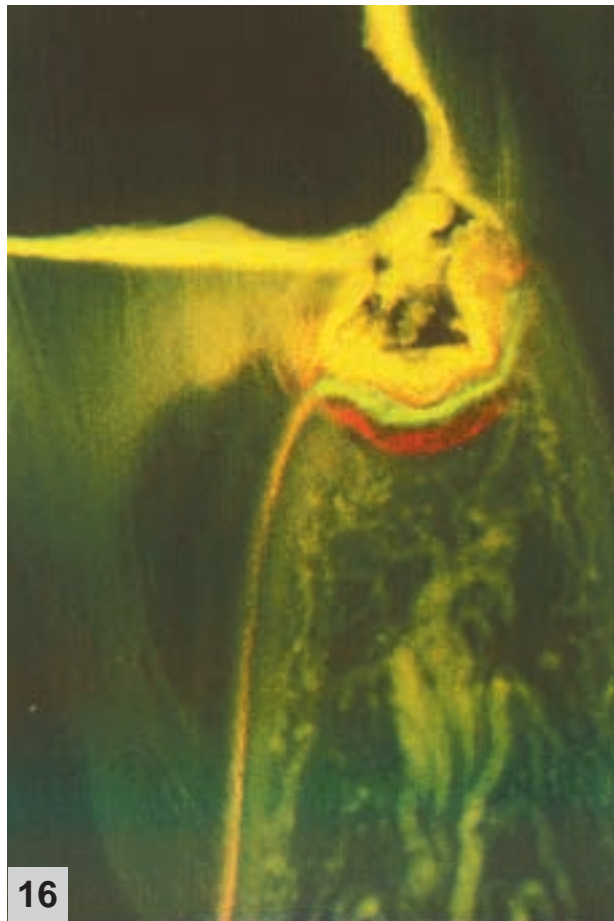
Fig. 15 Thermo-camera measurement after 5 laser pulses, each with 250 mJ/1 Hz on enamel (teeth stored in warm bath at 37 °C). The thermal effect is very low and limited in extension.



• Dental pulp

Histological investigations (Bib [2], [12], [22], [77]) based on animal experiments show that when the laser is applied correctly the pulp remains vital even after preparation close to the pulp or coronal opening of the pulp, and that the activation of the odontoblasts initiates the formation of reparative dentin. Subsequently a protective dentin bridge forms between the laser defect and the pulp (R [1], R [2]), see fig. 16.

Measurements of the microcirculation of the blood flow in the pulp prove that coronal application of the KEY laser to the pulp neither results in an irreversible standstill of blood circulation nor in a hyperaemic reaction (Bib [15]).





A 2.2 Nerves, pain sensation

While mechanical drilling instruments may trigger pain sensation due to various causes, such as

- vibration,
- pressure,
- heat / cold and
- noise,

no-contact laser preparation works without irritating the sensitive fibres of the pulp, thereby reducing the pain reaction significantly (Bib [106]).

Thus, a multi-centre study performed at 5 universities furnished scientific proof that laser treatment is preferred over treatment with the drill by the majority of patients. The laser pulses are perceived by some patients as a 'brief tapping' they say is not disagreeable (Bib [100]).

A 2.3 Mouth, oral mucosa

The effect of the KEY laser on soft tissue - just like its effect on enamel and dentin - can be described as a thermo-mechanical ablation process (Bib [10], [64]).

Since the strength of the soft tissue is lower than that of dental hard substance and its water content is greater, the ablation of an identical volume in soft tissue requires lower pulse energies. The cross section of an KEY laser cut does not have a carbonization zone and usually shows only a minimal necrosis zone (approx. 20-40 μm). There is virtually no evidence of oedema which is proof of the low depth effect of the heat induced by the KEY laser.

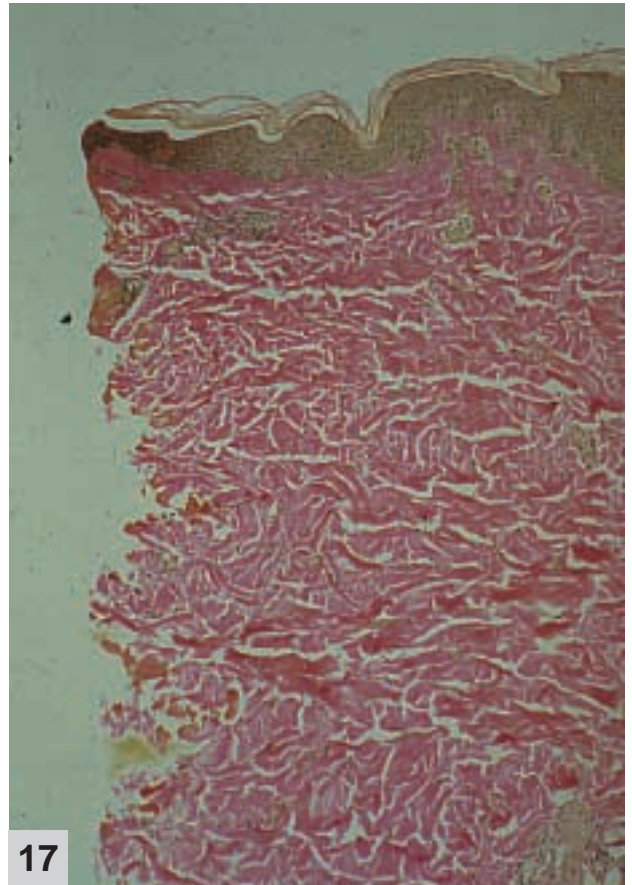
The width of the coagulation zone in soft tissue is hardly influenced by the pulse frequency and pulse energy level (fig. 17).

Fig. 17 Histology of an KEY laser cut in skin (250 mJ, 2 Hz). The width of the thermally induced coagulation zone is 30 - 40 μm .

The healing of KEY laser cuts takes place without delay and is identical in progress and duration to the healing of scalpel cuts.

At the macroscopic level, inadvertent laser exposure of the gingiva results in a defect that is usually round in shape. The greater the degree of defocusing, the larger the diameter and the lower the depth.

Lacerations - such as caused by mechanical injury from a rotating instrument - are not to be expected. Because of the low thermal effect of the KEY laser beam, bleeding which may reduce ablation efficiency is likely to be restricted to tissues well supplied with blood.



17



A 2.4 Bone

Bone ablation is also determined by the thermo-mechanical process because of the high water and hydroxyapatite content. High efficiency and a minimum of thermal stress in the depth of the tissue also prove to be advantageous here. [Bib. 11].

The width of the incision made in a K·E·Y Laser osteotomy is determined by the beam diameter and is approximately 1mm (Fig. 18) [Bib. 2]. As seen in scanning electronic microscope pictures the incision crevice is sharply defined, the incision margins show a micro-roughness of approximately 20µm whereby rosette-shaped configurations of hydroxyapatite crystals and bone trabeculae are visible. Carbonizations are histologically not visible (Fig. 19) [Bib. 2].

A K·E·Y Laser osteotomy progresses without delay via secondary bone healing through callous formation, as is supported by polarization microscope histology (Fig. 20) [Bib. 2].

The incision crevice is permeated within the first two to three weeks with connective tissue and collagenic fibroblast. Approximately four weeks after the osteotomy, the incision crevice is covered by newly-formed fibrous bone forming an internal connection to the adjacent bones present. Subsequently, the network bone transforms into lamellary bone about six weeks after the operation which, after about eight weeks, has the orientation of the local bone. Analogue to this, it could be shown fluorescently-microscopically that mineralization of the bone begins after one week, and, after six weeks, has already reached a high degree of mineralization due to the deposition of hydroxyapatite (Fig. 21) [Lit. 2].

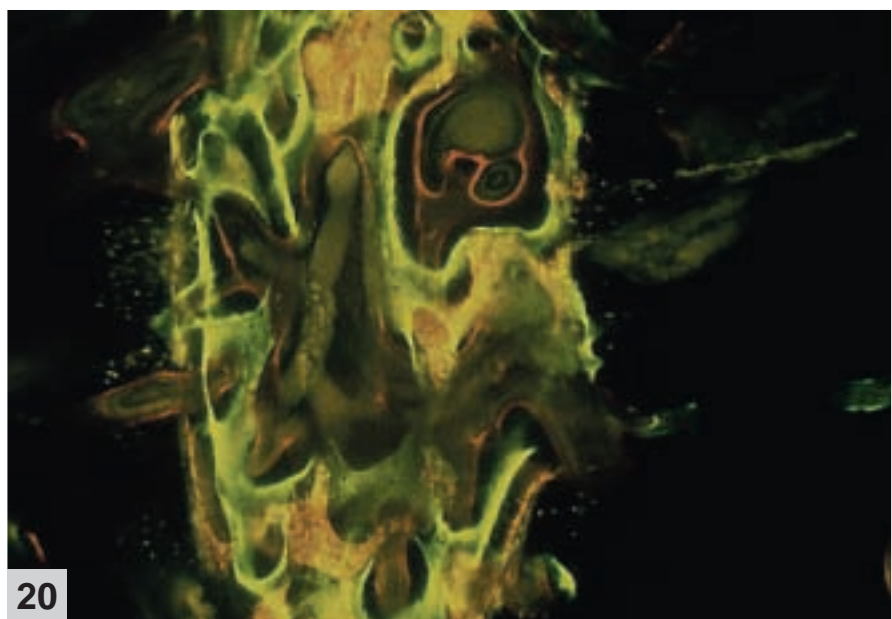
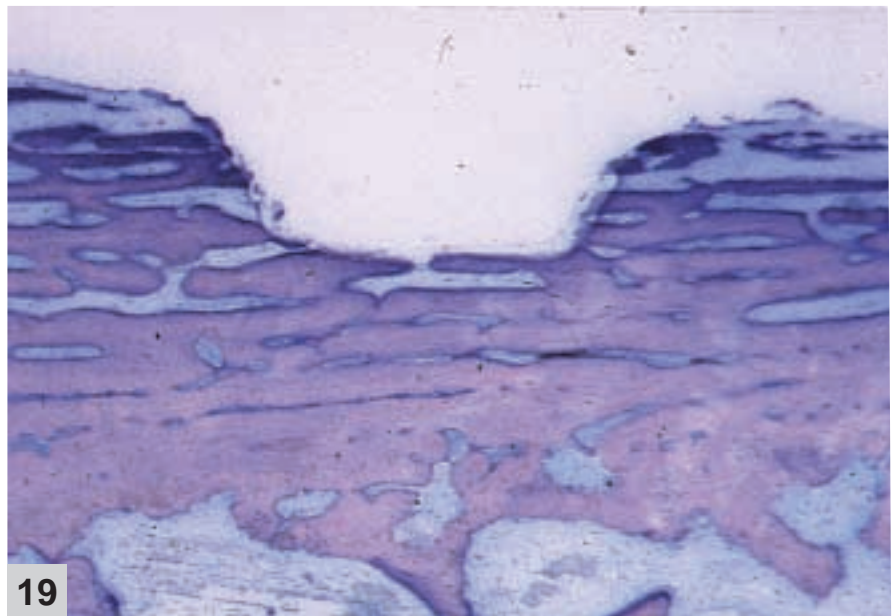


Fig. 18 X-ray picture following Er:YAG laser osteotomy at 300 mJ/3 Hz.

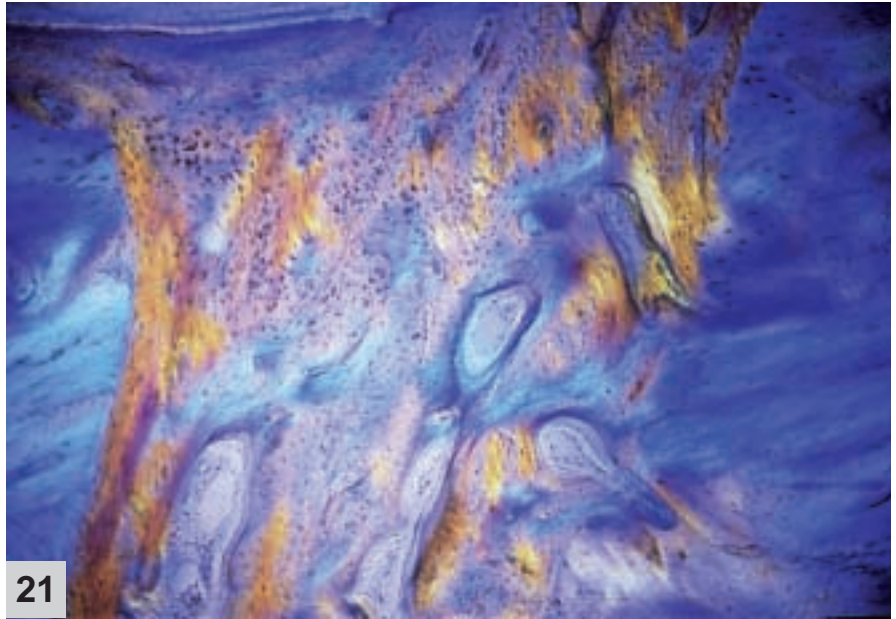
Fig. 19 Histology immediately following Er:YAG laser osteotomy at 200 mJ/1 Hz.

Fig. 20 Polarisation microscopy of canine lower jaw 8 weeks after Er:YAG osteotomy with 300 mJ/3 Hz (85x).

Similar to the new formation of dentin in treatment close to the pulp, an increase in the endosteum with subsequent new bone formation in the medullary space becomes apparent when, if the osteotomy is performed near the nerve canal, an intact bone bridges the laser defect and the nerve canal.

In order not to delay the healing of the wound, adequate moistening is recommended to prevent necrosis.

Fig. 21 Fluorescence microscopy 6 weeks following KEY laser osteotomy with 300 mJ/3 Hz 85x).





A 3 Safety aspects, effect upon the eye

Compared to the usual light sources such as light bulbs or neon tubes, laser radiation presents a special type of hazard as, technically, it can be directed parallel over a great distance or concentrated (focussed) on to a very small area.

The potential danger of laser is divided up into classes 1 to 4. Laser of the lowest classification level (e.g. a CD player) is not dangerous compared with laser of classification level 4 which can cause extreme damage to eyes and skin. The most important regulations stipulated in this connection are DIN EN 60.825-1 (VDE 0837 the safety of laser equipment, classification of plants), IEC 601-2-22 (medicine, laser devices) and the Professional Association's Accident Prevention Regulations VBG 93 including instructions for execution (user decrees).

The possible danger from laser radiation and its penetrating the eye depend mainly on its wavelength.

A 3.1 Light in visible and close infra-red

Light between 400 and 1400 nm is transmitted from the cornea, aqueous humour, lens and vitreous body and, if highly concentrated, can damage the retina.

Laser with these wavelengths are e.g. the Nd:YAG laser (at 1064 nm in invisible range, 1kW pulsed as used for retina attachment), the red pilot beam of the KEY laser (1242: 635 nm, 1mW / cw; 1243: 655 nm, 1mW / pulsed) or the light from a laser pointer (usually 670 nm, 1mW continuous). If the beam penetrates the eye limited by the pupillary aperture, the light source is focussed through the lens of the eye within the accommodation range of normally >100 mm and imaged on to a small area of the retina (fovea). In this concentration of light and local absorption, pigment epithel and the light-sensitive rods and cones can heat up and burn.

Depending on the length of exposure, sight can be temporarily or permanently impaired. If the fovea, which is essential for sight, is damaged the person affected is first of all aware of a dim, white spot covering the central sight range. The spot can darken within one to two weeks. The affected person is then normally no longer aware of this „blind spot“ unless he/she is looking „into space“ (or, for example, at a blank sheet of white paper). The ophthalmologist can test the eyes for damage by means of fluorescent angiography.

The pilot beam of a KEY laser is classified at level 2 which means that diffuse reflections such as occur following contact with skin can be considered unarmful. Looking for a short time (up to 0.25 sec.) directly into the focussed beam coming from the laser contra angle handpiece with and without optical means (e.g. magnifying glasses) is also considered to be safe as the eye usually protects itself by means of avertive reactions (e.g. optico-facial winking reflex). The relatively strong divergent spread of light after focussing or at the exit of the application fibres presents considerably reduced danger as the distance increases.

For reasons of safety, avoid looking directly into the beam emitting from the handpiece.

A 3.2 Light above 2500 nm

Light from the KEY laser treatment beam at 2.94µm (2940 nm) does not reach the retina but is absorbed beforehand by the aqueous substances of the eye (cornea, lens, vitreous humour etc.). Looking directly into the therapeutical beam of the laser contra angle handpiece and beginning at a safe distance, slowly bringing the eye towards it, heat impulses on the facial skin would be felt first, then the lacrimal fluid would evaporate and finally the epithelium of the cornea would be ablated. At first, these effects would be reversible. Further exposure would ablate the cornea and cause irreversible damage. If the eye were close to the focus on the first pulse, lacrimal fluid, epithelium of the cornea and cornea detachment would occur simultaneously and cause permanent damage.

In contrast to light in close infra-red, damage to the eye from a KEY laser beam would not go unnoticed but the warming effect of the infra-red radiation would cause it to be felt. Just as a desired removal of dental substance and soft tissue is possible, an undesirable ablation of the eye could also occur. The KEY laser is therefore classified under level 4 and safety goggles must be worn. The filtering effect of safety goggles (L4) reduces the power by factor 10^{-4} and provides adequate safety.

A 3.3 Basis for calculations

To enable the user to determine the safety area, determination of maximum permissible exposure (according to DIN EN 60 825) is shown as an example. Also demonstrated is the calculation of the area below which the maximum permissible exposure falls.

A 3.3.1 Maximum permissible exposure

The maximum permissible exposure represents the maximal assumed safe value to which a person may be exposed under normal circumstances without suffering eye or skin damage. The value is dependent on wave-length, pulse duration, effective time length etc. The approximate value is based on the best information available from experimental investigations and does not represent any precisely defined limits between dangerous and non-dangerous regulations. In all cases, potential danger is to be kept to as low as possible.

In the case of repeated pulsed laser, such as the pulsed Er:YAG laser beam from the KEY laser, the requirement a), b) or c) to be selected is the one which represents the greatest restrictions.

a) Single pulse

The value of the maximum permissible exposure for a single pulse is 2940 nm according to Table 6 of the EN60825-1 and has a pulse duration from 10^{-7} to 10 seconds for the eye (t in sec.).

$$H_{\text{single pulse}} = 5620 \times t^{0.25} \text{ J/m}^2$$

Pulse duration lies between 250 μs and 500 μs and is therefore calculated as 250 μs

$$H_{\text{single pulse}} = 5620 \times (250 \times 10^{-6})^{0.25} \text{ J/m}^2 = 707 \text{ J/m}^2$$

b) Average radiation strength of an impulse sequence

As the optico-facial winking reflex is not effective in invisible infra-red at 2940 nm, a value of 10 seconds is taken for adequate estimation of the effective time in the case of danger.

For this length of time, the total number of pulses (N) at varying equipment settings is determined in order to take into consideration the cumulative effect.

$$\text{Case I (400 mJ/15 Hz):} \\ N_{\text{I}} = 10 \text{ sec.} \times 15 \text{ Hz} = 150 \text{ pulses}$$

$$\text{Case II (600 mJ/10 Hz):} \\ N_{\text{II}} = 10 \text{ sec.} \times 10 \text{ Hz} = 100 \text{ pulses}$$

$$\text{Case III (100 mJ/25 Hz):} \\ N_{\text{III}} = 10 \text{ sec.} \times 25 \text{ Hz} = 250 \text{ pulses}$$

According to Table 6 of the EN 60825-1 radiation was limited to

$$H_{\text{T}} = 5620 \times 100^{0.25} \text{ J/m}^2 = 9994 \text{ J/m}^2 \\ \text{for an effective time of 10 seconds.}$$

If this dosis is distributed over single pulses at varying equipment settings, the average radiation of the single pulse is determined

for

$$\text{Case I } H_{\text{single pulse averaged}} = \\ 9994 \text{ J/m}^2 / 150 = 67 \text{ J/m}^2$$

$$\text{Case II } H_{\text{single pulse averaged}} = \\ 9994 \text{ J/m}^2 / 100 = 100 \text{ J/m}^2$$

$$\text{Case III } H_{\text{single pulse averaged}} = \\ 9994 \text{ J/m}^2 / 250 = 40 \text{ J/m}^2$$

c) Radiation through each single impulse of an impulse sequence

Radiation (from a) in an impulse sequence reduced by a correcting factor $N^{0.25}$ is:

$$\text{Case I } H_{\text{impulse sequence}} = \\ 707 \text{ J/m}^2 \times 150^{0.25} = 202 \text{ J/m}^2$$

$$\text{Case II } H_{\text{impulse sequence}} = \\ 707 \text{ J/m}^2 \times 100^{0.25} = 223 \text{ J/m}^2$$

$$\text{Case III } H_{\text{impulse sequence}} = \\ 707 \text{ J/m}^2 \times 250^{0.25} = 178 \text{ J/m}^2$$

The most restricting threshold when considering the above-mentioned criteria a), b) and c) results in the lowest threshold of a maximum permissible radiation of 67 J/m² (b) Case I), due to the cumulative effect at 15 Hz. Although lower frequencies allow higher pulse energy settings to be made on the equipment, these are compensated by higher permissible thresholds.

A 3.3.2 Safe distance

The distance from the focus of the laser contra angle handpiece or from fibre outlet is determined as safe distance (NOHD = Nominal Ocular Hazard Area) outside of which the exposure remains below the permissible value. The smallest beam divergency in KEY laser 1243 occurs at the outlet of the laser contra angle handpiece and lies just above 5°. An opening angle of 5° is therefore to be set. A maximum permissible exposure of 67 J/m² with a pulse energy of 400 mJ (15 Hz) remains below the permissible value with the following beam diameter.

$$D \geq \frac{4}{\pi} \times \frac{400 \text{ mJ/m}^2}{67 \times 10^3 \text{ mJ}} = 8,7 \text{ cm}$$

This beam diameter was exceeded in a distance of

$$\text{NOHD} \geq 8,7 \text{ cm} / (2 * (\tan(5^\circ/2))) = 99,6 \text{ cm.}$$

A distance of more than 99,6 cm from the focus of the laser contra angle handpiece or from fibre outlet of the application fibre is therefore considered to be safe.

If the above calculations are compared with the ablation thresholds determined for the Er:YAG laser (4500 J/m² for cornea; 7500-12000 J/m² for skin, Bib. [103]) and the ablation energy required per volume (0.83 kJ/cm³ for cornea, 1.5 kJ/cm³ for skin) the safety of the above calculations is confirmed.

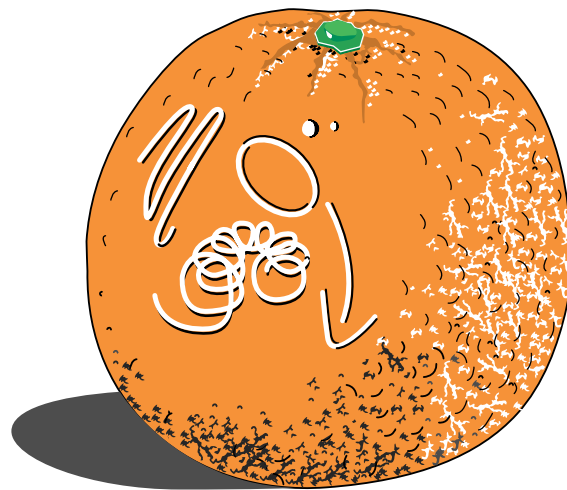
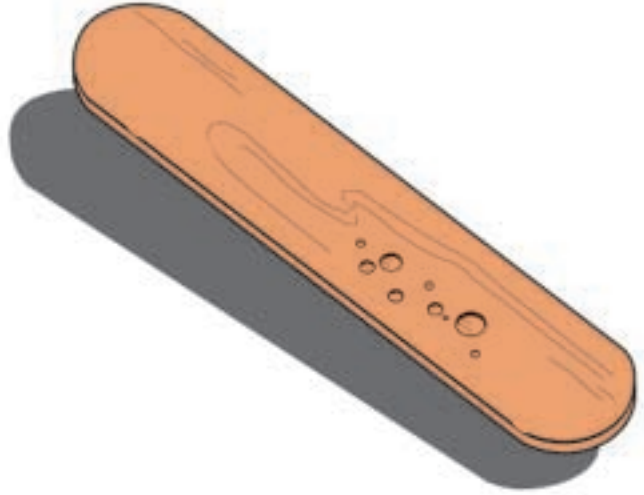


A 4 Test objects for laser applications

The test objects described below are intended for operator training with the laser.

Good laser instrument handling skills are usually attained after treating 20 to 40 teeth.

Test object	Objective of exercise
Moistened wooden spatula	<ul style="list-style-type: none">• Verification of working beam/pilot beam coincidence.• Testing for sufficient energy density by evaluating ablation performance.• Determination of focus size and focus distance from emission window.
Blotting paper, paper napkins, palm or back of the hand.	<ul style="list-style-type: none">• Spray adjustment.
Apple	<ul style="list-style-type: none">• Training of coordination of hand movements with triggering of laser pulses by actuating the foot control with and without spray.• Beam guidance.



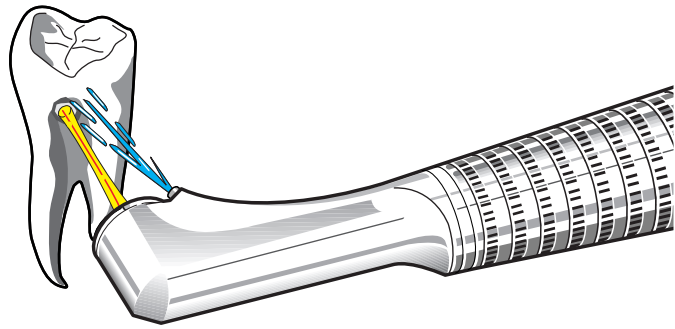
Extracted teeth

- Suction handling in conjunction with laser beam guidance.

- Evaluation of spray function in different treatment situations (water-filled cavity, cavities in the dental neck area).

- Intermittent usage of spray in fissures or water-filled cavities.

- Evaluation of ablation sound in water, enamel, healthy and carious dentin.



Pig's jaw

- Performance of cuts with focused application.

- Removal of extended areas of mucous membrane using defocused laser beam and high energy setting.



B 1 General notes regarding treatment

B 1.1 Operational notes

• Focus position

The axis position of the invisible KEY Laser working beam is identified by a red pilot beam. The optics of the laser contra-angle handpiece 2051/2060 have been designed such that the optimal working distance is approx. 12 to 15 mm in front of the laser emission window. Therefore the working distance of the K·E·Y Laser is approximately identical to that of mechanical motor instruments.

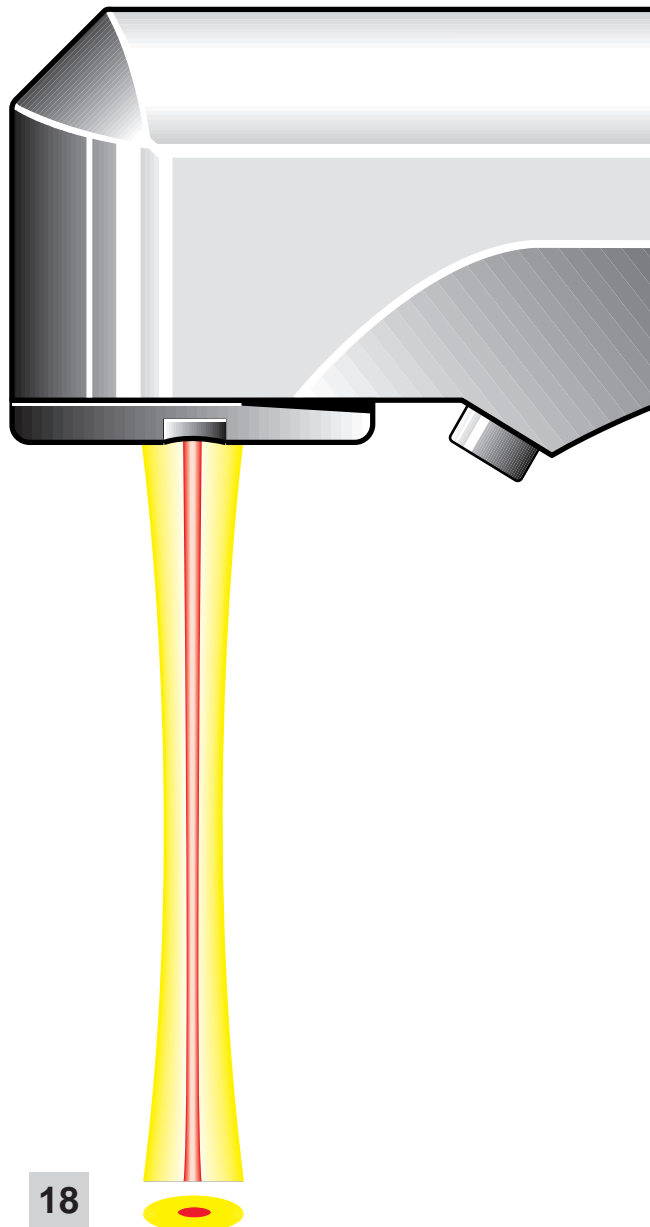
To facilitate laser handling, the laser contra-angle handpiece 2051/2060 is not sharply focused but has a narrow „beam waist“ assuring approximately identical focusing and operating conditions in the range of 10 to 20 mm in front of the laser emission window (see fig. 18, beam waist of K·E·Y Laser contra-angle 2051/2060).

When the laser emission window is held too close to the point of ablation, ejected tooth material may cause increased wear on the emission window.

• Spray

Spray is used for several purposes:

- a) Cleaning
Cleaning of ablation site and washing away of dental material removed.
- b) Ablation efficiency
Spray increases the ablation efficiency in enamel since coarsely crystalline, loosely adhering particles are removed by evaporating water.
- c) Assurance of ablation process
Keeping the ablation site wet maintains the ablation process, particularly in enamel, and prevents the tooth from drying out.
- d) Cooling
The K·E·Y Laser spray provides efficient tissue cooling during the ablation process (see section A 2.1).



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e) Shielding

The area surrounding the laser impact point is covered by a water film. This water film protects the area in which the energy of the laser beam is too low to effect ablation from unnecessary radiation.

f) Avoidance of odour

During laser treatment, ablated particles are partly melted when they fly through the air. If they are not removed by suction, then the ablation products can be perceived by their smell. The evaporated particles are bound together by the spray mist.

In order to achieve the desired effects, it is necessary to generate a thin water film on the tooth. The spray adjustment on the laser instrument should be based on the following criteria: If the water film is too thin, this may result in a brown discoloration of the dentin which is to be avoided. If the water film is too thick, the dental hard substance is not ablated; instead, only water is being evaporated.

In-vitro experiments without suction have shown a water flow of 1.5 ml/min to be sufficient. The water flow should be increased when treating a patient since individual suction techniques may draw off a part of the water spray before it reaches the operating site.

If an excessively thick water film already exists, the first foot control position (without spray) can be used to evaporate the water until the audible beginning of ablation. Then the operation can continue with the second foot control position and corrected spray setting (only 1242).

Once the correct spray adjustment has been found, the water supply to the tooth can be varied by moving the suction nozzle closer to or further away from the operating site.

The operator should also make sure the water spray is not prevented from reaching the operating site by cusps, tooth edges, etc.

• Suction

Since the generation of a thin water film only requires a small amount of water, use of the small suction nozzle is normally to be recommended. Increased suction can be used in case of unpleasant odour. Then, however, the spray volume should also be increased in order to prevent the operating site from drying out.

Scientific investigations of ablation substances (Bib. [84], [85], [92], [93], [112], [113]) showed that the industrial threshold limit value (TLV) legally stipulated for Germany (MAK) for individual substances were not exceeded. The use of a suction nozzle is recommended for occupational medical reasons.

• Probing for caries

When checking the bottom of a cavity by scraping with the dental probe, the point of the probe may occasionally get caught in a small crater or loosen healthy hard substance particles. This should not be misinterpreted as a symptom of caries. If this poses a problem, point-focal probing should be used instead in order to judge the hardness of the tooth substance. Handling the probe therefore requires some skill and experience.

• Guidance of laser instrument

When removing dental hard substance, the pulses should be placed next to each other, and the tissue should be removed layer by layer. The motion sequence is therefore different from the wiping movement performed with the turbine.

To obtain good adherence and marginal crevice sealing, particularly in the case of amalgam fillings, the laser beam should be guided perpendicular to the tooth surface while using spray. Vertical bombardment of the lateral cavity walls in the marginal area of the cavity should be avoided.

When cutting through soft tissue, the cutting line is to be drawn by a sequence of closely adjacent pulses. The cut can then be deepened by multiple passes over this line of pulses.

B 1.2 General contraindications

According to today's standard of knowledge, the following patients should not be treated with the K·E·Y Laser:

- Patients suffering from photodermatosis and photosensitive patients (photo-allergies).
- Patients suffering from serious illnesses of the haematogenic system (e.g., haemophilia, leukaemia).



B 1.3 Patient argumentation

The dentist can present the laser to the patient as a new, comfortable, less painful alternative to conventional treatment.

The following advantages can be cited:

- Minimally invasive intervention is possible.
- No-contact treatment.
- the germicidal effect of the laser beam.
- Improved visibility of the point of operation due to reduced spray mist and absence of drilling instrument.
- Caries can be selectively removed in a precise manner that is easy on the patient and tooth.
- Reduced noise.
- Vibrationless therapy.
- Reduced postoperative discomfort.
- Method of choice for patients with a phobia of injections or dentists.
- Ideally suited to treatment of children.
- It is a relief to the dentist not to have to cause pain to others.
- Reduced risk of side effects because the use of anaesthetics is avoidable.
- Treatment is less painful.
- Beneficial for patients with an intolerance to medicines, with allergies or cardiovascular problems.

B 2 Conservative therapy

B 2.1 Ablation of primary carious lesions distant to the pulp

(according to Prof. Dr. Keller)

Indication:

- Primary carious lesions in areas distal to the dental pulp.

Contraindications:

- none known

Laser type:

- K·E·Y Laser

Instruments:

- Laser contra angle handpiece 2051/2060
- Small suction nozzle
- Dental probe
- Motor instrument with finisher

Anaesthesia:

- Local anaesthesia is usually not required

Preparation:

- Take X-ray(s) if necessary
- Clean preparation site
- Adjust spray volume

Operating technique:

- Ablation with spray using the following laser parameters:

Instrument: 2051/2060	Pulse energy (mJ)	Pulse frequency (Hz)
Carious dentin	150-250	2
Healthy dentin	200-250	2
Enamel	300-400	2-3

- Check with the probe tip whether carious material is still present
- Finish cavity margin with motor instrument and finisher
- Clean cavity with a rotating brush and rinse.
- Dry cavity
- Base fillings and fillings as usual

Post-treatment:

- Post-treatment checks are not required

Notes:

- When making a cavity, the desired surface dilation should first be determined. From the commencement of the treatment, the laser beam is directed along the external circumference, placing one pulse next to another. When the starting point is reached again, the cavity is passed over once again if more depth is desired. The depth is formed layer by layer, by ablating the substances remaining in the cavity middle from the outside to the inside in concentric lanes after encircling the cavity margin. Work in the cavity middle progresses more and more quickly due to the increasingly smaller amounts of substance to be ablated. Working from the interior to the exterior would result in a funnel-shaped cavity and its depth would be difficult to control (see also Chapter B 1.1).
- When ablating enamel, attention must be paid that the beam is as focussed as possible. The laser beam is directed in a range of $\pm 10^\circ$ as vertically as possible onto the enamel surface so that an incline does not reduce the energy density at the ablation site.

Problems:

- None known

Advantages:

- Low-pain preparation
- Local anaesthesia is usually not required
- Targeted removal of caries, whilst retaining healthy dental hard substance
- Germ-free treatment

Bibliography:

- Bib [2], [3], [4], [5]
- Bib [7], [8], [12]
- Bib [15], [22], [23]
- Bib [31], [32], [37]
- Bib [79], [88]
- Bib [106]



Photographic documentation (Q [2]):

Fig. **B 2.1-1** Tooth 21 and 22 buccal, caries and abrasion before laser treatment with laser contra angle handpiece 2051 at 250 mJ/3Hz.

Fig. **B 2.1-2** Situation following caries excavation and laser drying with 80 mJ/2 Hz defocussed.

Fig. **B 2.1-3** View following filling





B 2.2 Ablation of primary carious lesions in dentin near to the pulp

(according to Prof. Dr. Keller)

Indication:

- Primary carious lesions in areas near to the dental pulp

Contraindications:

- none known

Laser type:

- K·E·Y Laser

Instruments:

- Laser contra angle handpiece 2051/2060
- Small suction nozzle
- Dental probe
- Motor instrument with finisher

Anaesthesia:

- Local anaesthesia is usually not required

Preparation:

- Clean preparation site
- Take X-ray(s) if necessary
- Vitality check
- Adjust spray volume
- Place rubber dam if necessary

Operating technique:

- Ablation with spray using the following laser parameters:

Instrument: 2051/2060	Pulsenergie (mJ)	Pulsfrequenz (Hz)
Dentin approx. to pulp	150-250	1, max. 2

- Check with the probe tip whether carious material is still present
- Finish cavity margin with motor instrument and finisher
- Clean cavity with a rotating brush and rinse
- Dry cavity
- When pulp has been opened artificially in healthy dentin, the opening should be capped directly with calcium hydroxide preparations
- Base fillings and fillings as usual

Post-treatment:

- If local anaesthesia has been used, perform a CO₂ snow vitality check no later than 1 week after the operation
- Otherwise perform vitality check immediately after treatment

Notes:

- The recommendation for mechanical preparation approaching the pulp is to reduce the instrument speed. Analogous to this, the laser pulse frequency should be reduced when approaching the pulp in laser preparations. The pulse energy setting plays a subordinate role with regard to the risk of pulp injury.
- Should the patient complain about pain, check to see if the recommended pulse energy range has been observed or whether excessively high pulse frequencies or inappropriate spray settings have been used.
- When the patient is being treated for the first time, it can be advantageous to emit a few laser pulses initially, then to make a short break so the patient can become accustomed to the unusual sensation.
- Mechanical pre-preparation may be recommendable for large-area cavity preparations.
- See Chapter B 2.1

Problems:

- In the area near to the pulp, the patient may perceive the laser pulses as needle punctures.

Advantages:

- Low-pain preparation
- Reduced postoperative discomfort
- Targeted removal of caries whilst retaining healthy dental substance
- Germ-free treatment

Bibliography:

- Bib [2]
- Bib [3]
- Bib [4]
- Bib [5]
- Bib [7]
- Bib [8]
- Bib [12]
- Bib [15]
- Bib [22]
- Bib [31]
- Bib [32]
- Bib [37]
- Bib [79]
- Bib [88]
- Bib [106]

B 2.3 Ablation of secondary carious lesions

(according to Prof. Dr. Keller)

Indication:

- Secondary carious lesions treated with composites (smaller cavities or residual composite) or cement

Contraindications:

- Amalgam fillings must be mechanically removed before laser therapy.
- Gold fillings cannot be ablated with the laser because gold reflects the IR radiation very well, and must therefore be mechanically removed before laser therapy.
- Crowns are to be mechanically removed before laser therapy.
- Ceramic materials normally cannot be ablated with the laser due to their lack of water content and the relatively high evaporation temperature of ceramic materials.
- Metals should not be radiated since they may heat up the surrounding tissue due to their high thermal conductivity.
- Metal chips ejected during ablation may injure peripheral tissue and damage the laser emission window.

Laser type:

- K·E·Y Laser

Instruments:

- Laser contra angle handpiece 2051/2060
- Large suction nozzle
- Dental probe
- Motor instrument with finisher

Anaesthesia:

- Local anaesthesia is usually not required

Preparation:

- Clean preparation site
- Adjust spray volume

Operating technique:

- Ablation with spray using the following laser parameters:

Instrument: 2051/2060

	Pulse energy (mJ)	Pulse frequency (Hz)
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Base filling cement		
Root-canal filling material	200 - 300	1, max. 2

Composite material	400	1 - 2
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- Laser therapy of secondary caries as described in section B 2.1 or B 2.2
- Base fillings and fillings as usual

Post-treatment:

- Post-treatment checks are not required

Notes:

- Removal of large composite fillings is relatively time-consuming.
- Note that composite removal predominantly takes place by composite evaporation. Due to the usually low thermal conductivity and high heat storage capacity of composite materials, a large composite filling can store a considerable amount of heat when bombarded continuously in conjunction with poor cooling.
- Large composite fillings should preferably be removed mechanically. The laser should then be used to ablate residual filling material and secondary caries in the areas more sensitive to pain.
- As an alternative, the filling margin can be ablated and the filling then be removed as a whole.
- The most efficient material removal is obtained when placing the pulses close together and ablating the filling in a circular fashion. Particularly with polyketones, carboxylate cement and composites, increased temperatures are achieved by increasing the pulse frequency rather than the pulse energy. Adequate spray supply must be assured in all cases.

- Applying too little pulse energy is not recommendable because this means that the energy is not used for the evaporation process.
- Fillings mixed with water (for example, carboxylate cement) or fillings causing the KEY laser light to be absorbed by hydroxyl groups can be removed more efficiently than those containing a high percentage of glass filler.
- Contrary to composites and phosphate cement, some whitish or brownish discoloration may occur when ablating carboxylate cement, glass ionomer cement and polyketones. However, this has no negative effect if the fillings are removed completely.
- Since the effects of evaporating filling materials have not been scientifically investigated from the point of view of occupational medicine, use of an efficient suction system is recommendable.

Problems:

- None known

Advantages:

- Low-pain preparation
- Targeted removal of caries whilst retaining healthy dental substance
- As a rule, no local anaesthesia is required
- Germ-free treatment

Bibliography:

- Bib [13]
- Bib [26]
- Bib [84]
- Bib [85]
- Bib [92]
- Bib [93]
- Bib [112]
- Bib [113]
- See sections B 2.1 and B 2.2



B 2.4 Dentin conditioning

(according to Prof. Dr. Keller)

Indication:

- Conditioning of dentin surface to promote filling adherence in cavities prepared with the K·E·Y Laser or rotating instruments

Contraindications:

- None

Laser type:

- K·E·Y Laser

Instruments, materials:

- Laser contra angle handpiece 2051/2060
- Small suction nozzle
- Adhesion promoters, e.g. Syntac
- Filling materials, e.g. Heliobond and Heliomolar or Durafillbond and Durafill

Anaesthesia:

- Local anaesthesia is usually not required

Preparation:

- Prepare cavity with rotating instrument or K·E·Y Laser
- Clean preparation site
- Adjust spray volume

Operating technique:

- The dentin surface is radiated with the defocused laser using spray and the lowenergy setting. The defocusing must be chosen such that the ablation threshold is slightly exceeded. An optimal energy density of 40 mJ/mm² is reached with a laser contra angle handpiece 2051 e.g. in a working distance of 20 mm (spot diameter 1.5 mm) at 80 mJ.
- in order to obtain homogenous dentin conditioning, the laser pulses are placed next to one another superimposed.

Laser parameters:

Instrument: 2051/2060

	Pulse energy (mJ)	Pulse frequency (Hz)
Dentin conditioning:	60-300 (defocused, ablative, 40 mJ/mm ²)	2-6

- Rinsing the surface
- Conventional drying of cavity or with K·E·Y laser.

When the K·E·Y laser is used for drying purposes, the laser is operated without spray and out of focus, slightly below the ablation threshold of the tissue (subablative). Tissue drying is discernible by a chalk-white discolouration or lightening of the prepared area.

Laser parameters:

Instrument: 2051/2060

	Pulse energy (mJ)	Pulse frequency (Hz)
Laser drying	60-100 (defocused, subablative)	2-6

- Apply an adhesion promoter
- Base fillings and fillings as usual

Post-treatment:

- Post-treatment checks are not required

Notes:

- Contrary to the acid-etch technique, the adhesion promoter can be directly applied.
- the treated edge must not be injured when treating coronal stumps and temporary fillings

Problems:

- None known

Advantages:

- Permits precision work.
- Use of acid is avoided. (if acid contacts the dentin surface of the prepared tooth, this may cause increased dentin permeability in the case of low dentin thickness, which may in turn lead to increased toxic influence of the composite on the pulp)
- The adhesive strength of the filling is significantly increased by dentin conditioning compared to purely mechanical preparation.
- Dentin conditioning with the K·E·Y Laser is suitable particularly for cosmetic structures on the anterior teeth in conjunction with composite fillings.
- Dentin conditioning with the K·E·Y Laser improves filling adhesion even with mechanically prepared cavities, particularly in the case of fillings with low retention due to a lack of substance in the enamel.
- Disinfecting the lasered surface

Bibliography:

- Bib [46]
- Bib [48]
- Bib [79]
- Bib [81]
- Bib [120]

B 2.5 Enamel conditioning

(according to Prof. Dr. Keller)

Indication:

- Conditioning of dentin surfaces to promote filling adherence of composites in cavities or dental areas which have been treated by KEY Laser or rotating instruments.

Contraindications:

- None are known

Laser type:

- K·E·Y Laser

Instruments, Materials:

- Laser contra angle handpiece 2051/2060
- Small suction nozzle
- Adherent: adhesive bond
- Filling material: fine hybrid composite Charisma (Heraeus-Kulzer)

Preparation:

- Treatment by means of rotating instruments or K·E·Y Laser
- Cleaning of treated sites
- Adjustment of spray volume

Operating technique:

- Using a drill, bevel the cavity rims.
- The site to be treated is lasered using simultaneously a light spray. The surface is treated in five passes with semi-superimposed laser pulses. If flat enamel is being treated, then perpendicular parallel passes are recommended. An energy density of 200 mJ/mm² has proven to be optimal. At 350 mJ, this corresponds to a spot diameter of 1.5 mm (2051: emission window approx. 20 mm distance from the tooth). The pulse frequency is adapted to the site being treated. If the site to be conditioned is small, a lower pulse frequency is selected.

Instrument 2051/2060

	Pulse energy (mJ)	Pulse frequency (Hz)
Enamel conditioning (defocused ablative, 200 mJ/mm ²)	350	2-10

- If additional adherence is required, the laser conditioning can be followed by the usual acid conditioning.
- Rinsing the surface
- Drying the surface in the conventional way or preferably by means of KEY Laser. Drying with KEY Laser is carried out without spray and defocussed whereby the ablation threshold of the tissue is subablative. Tissue drying can be recognized by a chalk-white discoloration or lightening of the treated site.

Laser parameters:

	Pulse energy (mJ)	Pulse frequency (Hz)
Laser drying (defocussed subablative)	60-100	2-6

- Application of bonding (adhesive bond)
- Application of filling material (Charisma) as usual

Post-treatment:

- No post-treatment checks are required

Observations:

- While with laser conditioning (10.8 ± 2.3 MPa) without acid application the same level of adherence was obtained as with acid etching (10 MPa ± 1.5), an increase in adherence (to 13 MPa) was achieved through a combination of laser and acid conditioning.
- The combination of both processes could be applied to cases where, because of lack of substance or high stress, a higher degree of adherence is desired.
- Depending on the amount of enamel treatment to be carried out, loose enamel particles may have to be removed.

Problems:

- None are known

Advantages:

- Permits precision work
- Combination of laser and acid results in a higher degree of adhesive strength
- KEY Laser can be used as an alternative to acid, saving time and effort necessary for acid etching work.
- As it is possible to do without cavity rinsing after the conditioning, it is easier to keep the etched area dry and to protect it from contamination from saliva.
- Laser drying is very quick compared with chip syringing and therefore less stressful for the patient.

Disadvantages of the acid etching:

- In some cases etching can be irregular in parts where enamel sites have not been dissolved by the acid.
- In some cases uncontrolled depth intensity of the acid etching due to enamel permeability or penetration in approximal sites and crevices or fissures.
- A strong acid effect and subsequent composite coverage could lead to acid residue due to inadequacies and, in parts, difficulties in controlling water rinsing which carry the hidden danger of progressing acidolysis.
- If the acid is sprayed off and removed by suction, it can reach uncontrolled parts of the mouth where etching is not desired.
- Acid has the property of releasing fluoride which is necessary to caries resistancy. Through the often inexact application of liquid acid, the enamel beyond the bevelling can be etched and the protective function in this area is lost until calcium and phosphate ions in the saliva have provided re-mineralization within a period of one to three weeks.

Literature:

- Bib. [29]
- Bib. [35]
- Bib. [67]
- Bib. [68]
- Bib. [79]
- Bib. [81]



B 2.6 Fissure sealing

(according to Dr. Geibel and Prof.Dr. Raab)

Indication:

- Sealing of non-carious molars and pre-molars
- Extended fissure sealing after pre-treatment of a carious fissure

Laser type:

- K·E·Y laser

Instruments, materials:

- Laser contra-angle handpiece 2051/2060
- Rubber dam
- Small suction nozzle
- Small brush, pumice powder
- 35% orthophosphoric acid
- Sealing plastic, Helioseal (Vivadent), Delton clear (De Trey)

Anaesthesia:

- Local anaesthesia not required

Preparation:

- Prepare rubber dam
- Clean fissures with brush and pumice powder

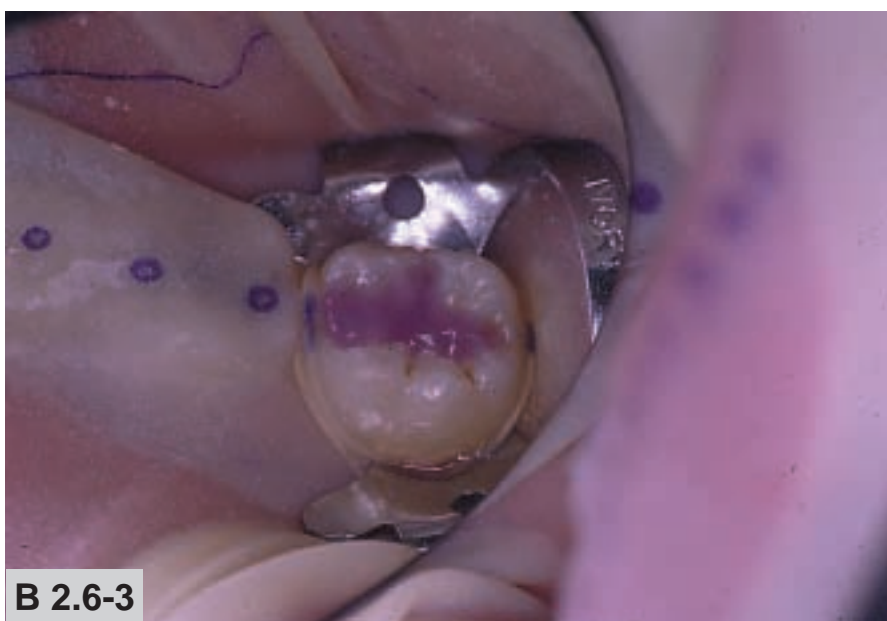
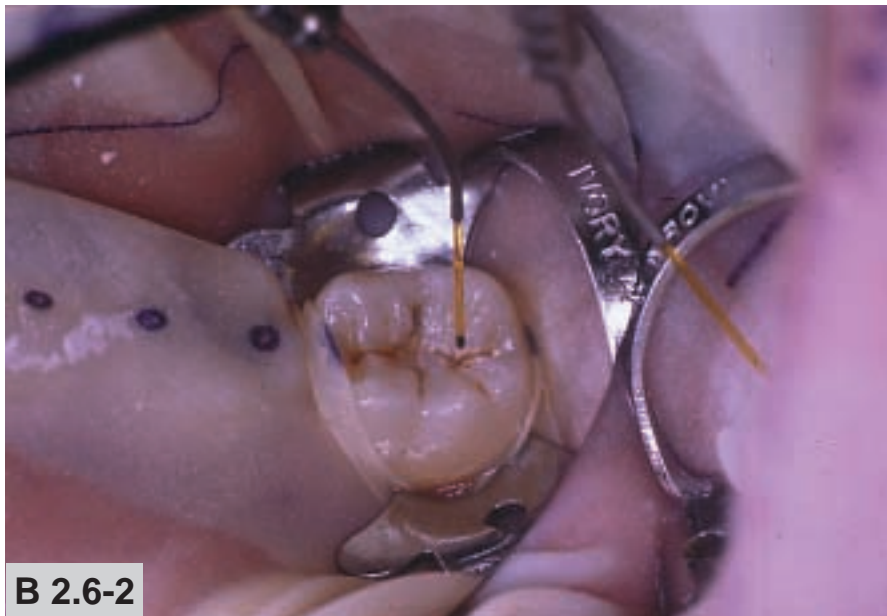
Operating technique:

- Fissure conditioning with spray supply using the following laser parameters:

Instrument: 2051/2060

	Pulse energy	Pulse frequency
	(mJ)	(Hz)
Fissure conditioning	120-220	2

- Acid etching with 35% orthophosphoric acid (30 s)
- Clean with water spray (30 s)
- Seal with Helioseal (Vivadent), Delton clear (De Trey)



Post-treatment:

- Occlusion check
- Fluorination

Problems:

- None known

Advantages:

- Complete removal of organic deposits in the fissure
- Improved bonding between sealing material and laser-prepared enamel
- Improved sealing of the marginal gap
- In preventive fissure sealing it is not necessary to lance the fissure with the finest diamond.

Bibliography:

- Bib [51]
- Bib [76]
- Bib [94]
- Bib [97]

Photographic documentation (Q [6]):

Fig. **B 2.6-1** Tooth 37 prior to fissure sealing. Patient, female, 13 years old.

Fig. **B 2.6-2** Fissure conditioning with laser handpiece 2055, fibre insert 50/10 at 120 mJ applied pulse energy 2 Hz.

Fig. **B 2.6-3** Acid conditioning with 35% orthophosphoric acid

Fig. **B 2.6-4** Situation following laser conditioning and acid conditioning

Fig. **B 2.6-5** Fissure sealing with Helioseal

Fig. **B 2.6-6** Tooth 37 after completed fissure sealing





B 3 Endodontics

B 3.1 Root canal disinfection

(according to Dr. Hibst P.D.)

- X-ray to determine canal length
- Mechanical treatment lege artis up to at least ISO 30 and complete removal of infected substance using the normal rinsing
- Drying of canal with paper tips
- Placement of stops on fibre inserts

Indication:

- Germ reduction in root canal following mechanical preparation in vital exstirpation or treatment of an infected canal.

Contra-indication:

None known

Laser type:

K·E·Y Laser

Instruments:

- Laser contra angle handpiece E 2055/2062 with fibre inserts 30/28, 40/28 and 50/28
- Small suction nozzle

Anaesthetics:

- Root canal disinfection on a devital tooth, as a rule, does not require anaesthetics

Patient information:

- The attending dentist can inform the patient that in connection with the germ-destroying effect a slight sensation of warmth could be experienced. In this case, the patient should inform the attending dentist of any pain so that the treatment parameters can, if necessary, be reviewed.

Preparation:

- Sterilize freshly abraded fibre inserts (see instructions for use, in the manual) and just before use, check flexibility by pulling, bending and axial stress.
- Trepanation, opening of pulpakavum and exstirpation of pulpa lege artis.

Operating technique:

- The fibre size corresponding to the ISO size being used is directed apical into the canal and positioned 1mm from the apex
- Following this, pulses are released using the foot control preferably in position 2 (with air cooling of the fibre insert)
- After emitting the laser pulses, the fibre is pulled out of the canal from apical to coronal using circular motions (about 2 sec./revolution).
- This procedure is repeated several times whereby an interval of at least 10 seconds is made between every second motion.
- The rate of removal, the laser parameters and the number of repetitions depend on the radial wall thickness of the tooth (residual dentin thickness) in the radiated area. This is to be first estimated with the help of the X-ray. The adjacent table serves as an orientation in the selection of parameters. If the residual dentin thickness **D** is 1-1.5 mm, a frequency **f** of 15 Hz is selected. The fibre is removed from the canal at a rate of **v** = 2 mm/sec. This procedure is repeated four times for a canal corresponding to ISO size 50 (**n**, number of passes).

D mm	f Hz	v mm/sek	n	
			ISO 50	ISO 30
0,5-0,7	6	2	10	6
0,8-0,9	10	2	6	4
1,0-1,5	15	2	4	3
> 1,5	15	1,5	3	2

Laser parameters:

Instrument E 2055/2062

	pulse energy (mJ)	pulse frequency (Hz)
Root canal sterilization	50 (120-160)*	6-15

Setting of equipment according to fibre insert (please observe manual)

Footnote:

* the numbers in brackets denote the relevant settings for the equipment. (please observe manual)

Post-treatment:

- If necessary, provisional filling with calcium hydroxide and further endodontic provision lege artis.

Observations:

- Some laser pulses are already germicidal, the effect of individual pulses is cumulative. An overall dosis of 100 J/cm² is required to achieve an efficient germicidal effect. The required energy increases with increasing wall area, thus with the root canal diameter.
- On the other hand, the warming of the tooth and the surrounding bone from the use of laser is determined in the main by the irradiation used in each individual pass. In order to avoid even a short-term warming of the desmodont or jaw of more than 10° C, the selected frequency of the pulse sequence must not be too high and the removal rate of the fibre not too slow. With decreasing dentin thickness between root canal and desmodont, the maximum permissible pulse frequency and/or minimum removal rate is reduced. In both cases, fewer laser per mm of the root canal length reach the wall of the root canal so that in order to reach the necessary overall dosis more passes are required.
- The following procedure is recommended when practising manual movement of the fibre and a visual control of the removal rate on an extracted tooth:
 - Determine length of canal (e.g. 15 mm long) Taking into account the apical distance of 1mm, pulses are sent along a length of 14 mm. If the removal rate is 2 mm/sec, one pass in the canal thus takes 7 seconds (14/2=7), If 15 Hz is set, 105 pulses (7x15=105) are to be given for each pass. This given number of pulses is to be compared at the end of the procedure with the number of pulses shown on the display.
 - Set the pulse counter on the display to „0“ by pressing the Ready button.
 - remove the fibre with the above-mentioned parameters from apical to coronal.
 - Stop the pulse emission on reaching the canal entrance
 - Compare the given number of pulses with the number shown on the display and, if necessary, adjust the removal rate.
- To treat canals which are badly contaminated with bacteria, it is recommended to make use of the cumulative bactericidal effect of the laser and, if necessary, increase the number of passes.

- The effective range of laser light up to 3 mm away from the fibre end surface.
- Circling the fibre serves to radiate the circumference of the canal wall as evenly as possible. If the fibre is apical, the distance to various places on the circumference is relatively even due to the narrow space available for guidance. If the fibre is coronal, then the circumference is in parts large and meandering. Especially in these areas, it is advisable to pass along the circumference of the meandering with the end of the fibre in order to reach all parts of the canal wall.
- The exterior diameter of the fibre of the fibre insert, size 40/28, is a little less than 0.4 mm so that for an introduction of this size the canal must be prepared at least according to ISO 40. If the canal is only prepared up to ISO 30 or 35 there would be a danger of a size 40 fibre becoming wedged and sitting tight.
- If the continuous removal of the fibre is hampered by becoming hooked in or hindered in a similar way, the pulse emission must be stopped with the foot control until it can be moved freely once more.
- In cases of acute and painful apical inflammation the patient should be given provisional treatment for the pain in the initial session without laser and then later endodontical treatment with laser.

Problems:

- None are known

Advantages:

- Efficient germicidal effect
- Good drying of the canal
- Comfortable treatment
- Good apical application of germicidal effect by means of flexible fibre compared with chemical rinses which can be hindered by narrow canals
- Compared with NaOCl rinses less danger from splashes or over-injection.

Bibliography:

- Bib. [102]
- Bib. [114]
- Bib. [118]



B 4 Surgery

B 4.1 Incision, excision

(according to Prof. Dr. Keller)

Indication:

- Incision for drainage of abscesses
- Frenectomy, incision on frenulum of the cheek
- Excision of fibromas and flap fibromas
- Gingivectomy in the case of hyperplasias of the gingiva or excision of hyperplasias
- Preprosthetic surgery: flabby alveolar ridge, vestibuloplasty, exposure of implants, hyperplasias, epulides, papillomas, fibromatoses, benign growths

Contraindication (according to today's standard of knowledge):

- Malignant tumours, obligate precanceroses, haemangiomas

Laser type:

- K·E·Y laser

Instruments:

- Laser contra-angle handpiece 2051/2060
- Small suction nozzle
- Forceps

Anaesthesia:

- Local anaesthesia may be required

Preparation:

- Cleaning of preparation site or disinfection with Chlorhexamed
- Adjustment of spray quantity

Operating technique:

- Hold frenulum or fibroma with tweezers (pulling slightly) and cut off using spray and the following laser parameters:

Instrument: 2051/2060

	Pulse energy (mJ)	Pulse frequency (Hz)
Incision		
Excision	60-300	4-10 (max. 15)

- Clean preparation site with Chlorhexamed or 3% H₂O₂

Post-treatment:

- Application of healing ointment (e.g. Dantisolon, mouth rinse, e.g. Chlorhexamed, sage tea)
- Routine checks after 1 to 10 days, 3 to 6 weeks

Notes:

- When performing incisions, we recommend superimposing several pulse rows rather than working down to the desired depth and then attempting to extend the cut. This has the advantage that unintentional perforation can be avoided.
- Since the ablation depth of the individual pulses depends directly on the pulse energy setting, low cutting depths can be controlled best using a low energy setting and by superimposing several pulse rows one upon another.

Problems:

- Should ablation be obstructed by heavy bleeding, increase suction or tension the tissue somewhat.

Advantages:

- Simple operating technique without carbonisation zones and with minimal necrosis
- Reduced strain on patient during treatment
- Excellent viewing conditions at operating site help distinguish diseased from healthy tissue
- Reduced bleeding tendency
- Slightly styptic effect due to drying of tissue when working with high frequencies and low energy
- Reduces germs at operating site
- No suture or plastic soft-tissue coverage necessary for excision
- Wound heals without delay, chronologically and histologically similar to scalpel cuts
- No or reduced post-operative pain therapy due to reduced tissue trauma
- Reduced formation of oedemas and swelling
- Complete epithelisation of surgical wound without scar contraction
- Reduced hardening of oral soft tissue

Bibliography:

- Bib [6]
- Bib [10]
- Bib [64]
- Bib [65]
- Bib [69]
- Bib [109]

Photographic documentation (Q [2]):

Fig. **B 4.1-1** Hyperplasia on tooth 38 prior to laser excision with laser handpiece E 2055, fibre insert 50/10 at 250 mJ*/15 Hz

Fig. **B 4.1-2** Tooth 38 after exposure





B 4.2 Ablation of extended areas of diseased oral mucosa

(according to Dr. Keller ,PD.)

Indication:

- Simple diseases of the oral mucosa, e.g. leucoplakia simplex, idiopathic leucoplakia, lichen ruber planus, hyperkeratoses, aphthas

Contraindication (according to today's standard of knowledge):

- Malignant tumours, obligate precanceroses, haemangiomas

Laser type:

- K·E·Y laser

Instruments:

- Laser contra-angle handpiece 2051/2060
- Large suction nozzle
- Moist swabs

Anaesthesia:

- Local anaesthesia may be required for larger defects
- No local anaesthesia for small defects or low energy settings

Preparation:

- If precancerosis is suspected, perform test excision before laser ablation
- Sterile water must be used for spray
- Adjust spray quantity

Operating technique:

- Use spray if this is agreeable to the patient (e.g., in cases of extended exposure or high pulse energy)
- Circular radiation of tissue to be removed
- Adapt defocusing of beam (dia. 2-4 mm) to size of tissue area to be treated
- Place individual pulses in a row until the subepithelial connective tissue is reached, i.e. slight bleeding occurs
- Laser parameters

Instrument: 2051/2060

	Pulse energy (mJ)	Pulse frequency (Hz)
Ablation of extended areas of oral mucosa (defocused)	60-350	1-10

Post-treatment:

- Removal of ablated tissue with a moist swab
- Application of an indifferent healing ointment on the treated areas of the mucous membrane (e.g. Dontisolon, Volon A ointment), mouth rinse with Chlorhexamed
- Routine checks after 1 to 10 days, 3 to 6 weeks

Notes:

- None

Problems:

- None known

Advantages:

- Simple operating technique without carbonisation zones and with minimal necrosis
- Reduced strain on patient during treatment thanks to no-contact treatment
- Excellent viewing conditions at operating site help distinguish diseased from healthy tissue
- Extended plastic coverage of defect is usually unnecessary, suture is unnecessary
- Reduced bleeding tendency
- Reduces germs at operating site
- Primary plastic measures to cover mucous membrane defects are usually not required
- Eliminates or reduces necessity of post-operative pain therapy due to reduced tissue trauma
- Minimal formation of oedemas
- Complete epithelisation of surgical wound without scar contraction
- Reduced hardening of oral soft tissue
- Reduced swelling of wound
- Wound heals without delay, chronologically and histologically similar to scalpel cuts
- Treatment usually does not result in reduced function

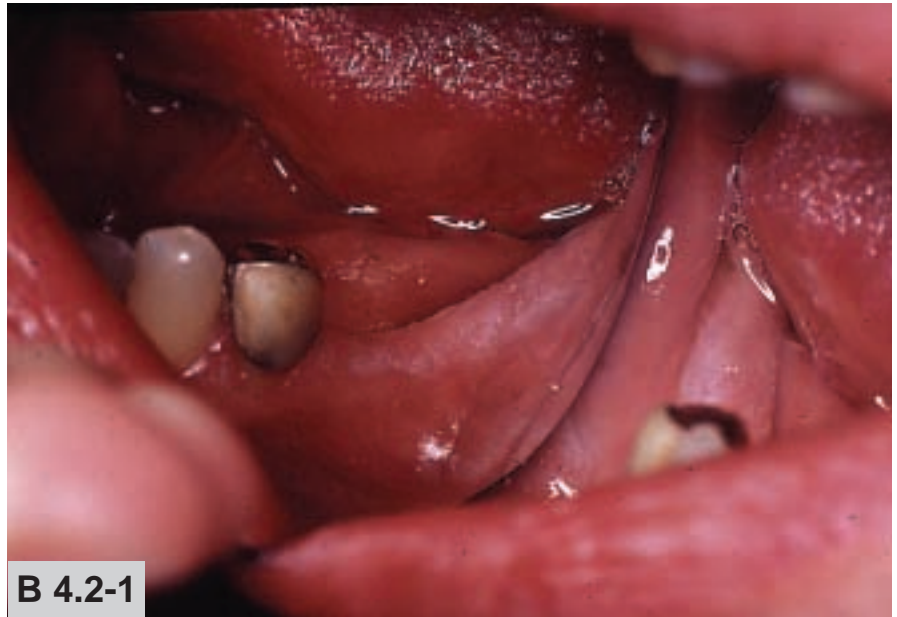
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- Bib [109]

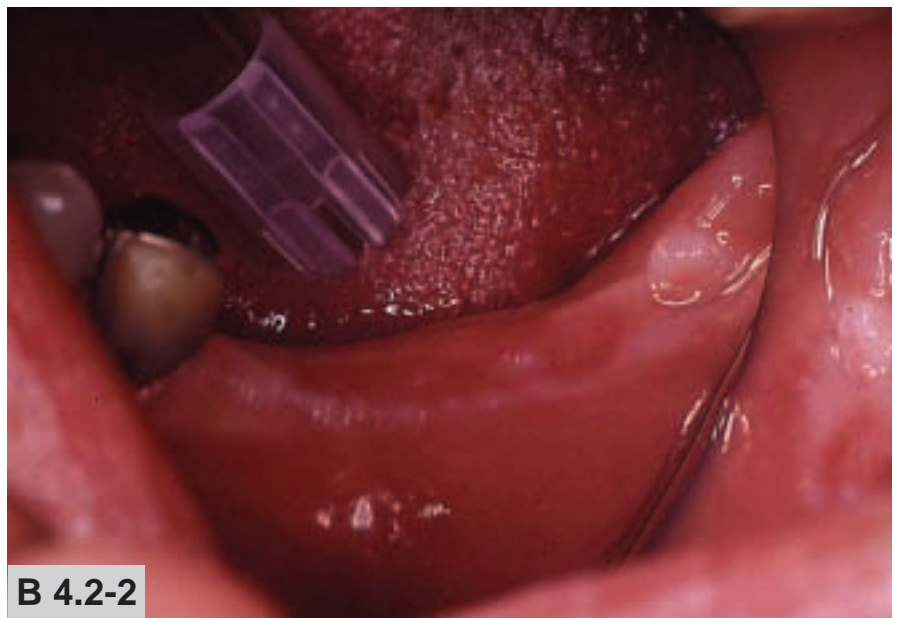
Photographic documentation (Q [2]):

Fig. **B 4.2-1** Leucoplakia on alveolus appendix prior to laser ablation with laser handpiece E 2055, fibre insert 50/10 at 250 mJ*/10 Hz.

Fig. **B 4.2-2** Leucoplakia 3 days post operative



B 4.2-1



B 4.2-2



B 4.3 Implant exposure
(according to Prof. Dr. Keller)

Indication:

- Exposure of implant post following trans- or subgingival healing in the alveolus by means of excision or incision of the mucosal cap in two-phase implants. The implant cap (plastic, metal or ceramic) must cover the implant post completely.

Contraindication:

None known

Laser type:

- K·E·Y Laser

Instruments, Materials:

- Laser handpiece E 2055/2062 with fibre insert 50/10
- Laser contra angle handpiece 2051/2060
- Surgical suction device preferably with flexible plastic cannula
- Forceps, raspatory
- Cotton wool or swab saturated with H₂O₂ (5%)

Anaesthetics:

- The use of an infiltration anaesthetic is recommended for pain-sensitive patients.
- Less sensitive patients can be given a surface anaesthetic or be treated without anaesthetics. If no anaesthetic is administered, the patient should be informed that he/she might experience a sensation of warmth in the mucous area caused by the germicidal effect of the laser and that the sensation will disappear after treatment has ended.

Preparation:

- X-ray check
- In case of completely covered implants, the location of the implant post is to be determined by means of a detector or by making an implant pattern. The middle of the implant is marked by a dot, or alternatively the implant circumference with a circle on the mucous using a coloured marker pen.

Operating technique:

- The incision is carried out by means of laser handpiece E. Two incision methods are possible.
 - Mesio-distal incision.
The mucous and the periost are separated 1-2 mm above the middle of the implant in the mesio-distal direction. The slit gingiva is mobilized by means of a raspatory or similar device so that afterwards an impression post or gingiva margin former can be applied. This minimal invasive procedure is suitable in cases where little gingiva is present.
 - Circular incision.
A breakthrough point is indicated on the marked spot of the implant middle and by means of a probe the location of the implant centre is controlled. Then a circular incision is made around the edge of the implant cap. The tissue which will later form the implant seam is modelled aesthetically by means of laser contra angle handpiece so as to ablate tissue residue and form a fine edge to the circumference. The laser beam can be directed below 45° away from the implant. For incision with the laser handpiece E the fibre (50/10) is directed close to the surface in order to make an efficient incision with a beam as small as possible. Down-pressure on the tissue is avoided so as to protect the tissue and to prevent the fibre from adhering. Due to the relatively small blood vessels in the tissue, only a small amount of bleeding is to be expected. Suction should be carried out as closely as possible to the incision site. The treated site is to be freed from ablated tissue and blood at intervals with a cotton wool pad soaked in v.

Laser parameters:

Instrument E 2055/2062 with fibre insert 50/10

	appl. pulse energy (mJ)	pulse frequency (Hz)
Implant exposure	100-140	10-15
Incision	(180-250)*	

Instrument

- 2051/2060

Implant exposure

Modelling	160-250	4-10
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Footnote:

* the numbers in brackets denote the relative device settings (please observe manual)

Post-treatment:

- Due to reduced bleeding tendency, it is possible to make an impression for the making of the supraconstruction immediately after implant exposure and insertion of an impression post.
- Alternatively, because the tissue quickly regenerates without complications, the impression can be carried out 1-3 weeks after the exposure in order to take into account stationary mucogingival conditions.

Observations:

- Ceramic surfaces are normally not ablated with laser beam. As a rule, metal surfaces can be modified using high energy density depending on the degree of soiling and the condition of the surface and material (e.g. direct contact with fibre). Reflecting surfaces generally reflect a large part of the radiation. Plastic surfaces promote material ablation and hardly reflect. As the implant cap is discarded anyway after use, no problems are to be expected here. Direct laser radiation of the implant over a long time is to be avoided so as not to impair the implant/bone surface through warming.

- At intervals, free the fibre point from residual tissue using a cotton wool pad or swab soaked in H₂O₂ to clean the fibre coating. The outlet area of the fibre can be abraded and cleaned with the enclosed abrasive paper if a decrease in power is noted.

Advantages:

- Compared with the punch, working with KEY laser causes less bleeding which reduces the danger of contamination of the implant with residual blood and tissue after removing the closing screw.
- The execution of the gingiva incision is less stressful and more exact than when using a punch. As it is difficult to centre the punch exactly, a lot of valuable gingiva tissue is unnecessarily lost in this method.
- It is less traumatic than using a scalpel as contact-free incision means no pressure must be exerted. The execution of incision pressure means the tissue gives way and makes an exact incision more difficult. In addition, there is also the danger of bone injury with a scalpel.
- Formation of good fibrous and periosteal closures in the shortest time.
- Time-saving, as impression taking and possible gingiva plastic to thin out too much mucous coverage can be carried out in the same treatment session.

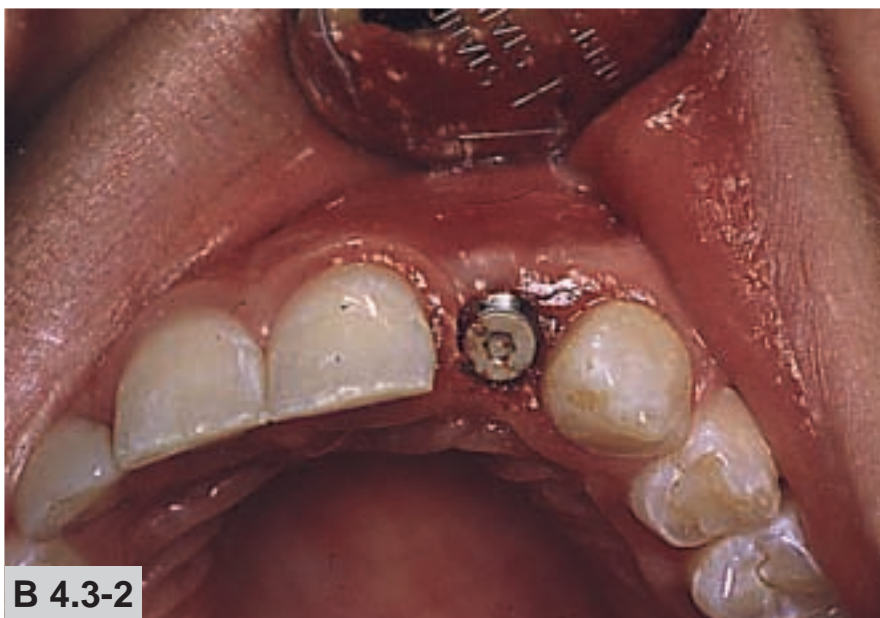
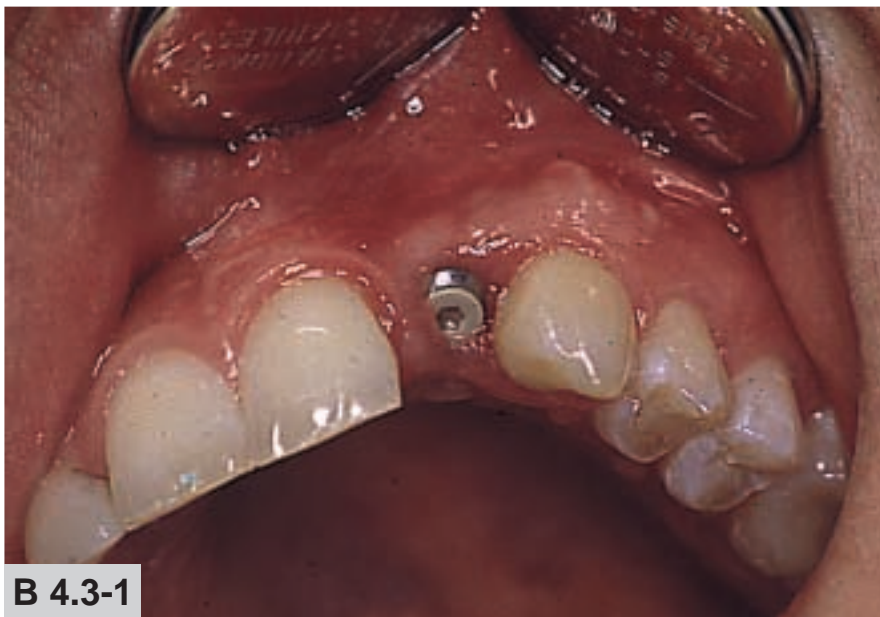
Bibliography:

- Bib. [10] - Bib. [64]
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Photographic documentation:

Fig. **B 4.3-1** Bonefit implant in regio 22 prior to exposure with laser handpiece E2055, 50/10

Fig. **B 4.3-2** Implant after exposure with 180mJ*





B 4.4 Fibroma excision

(according to Prof. Dr. Keller)

Indication:

- Stemmed fibroma, wide-based fibroma, flapped fibroma on hard/soft gums, buccal mucous membrane, lips, edge or base of tongue and gingiva, hyperplasia especially epulis, granuloma teleangiectaticum

Laser type:

- K·E·Y Laser

Instruments, materials:

- Laser handpiece E 2055/2062 with fibre insert size 50/10
- Surgical suction nozzle (preferably with flexible plastic cannula)
- Surgical forceps
- Swabs soaked in H₂O₂ (5%) or NaCl

Anaesthetics:

- The administration of an infiltration anaesthetic is recommended, if the patient is pain-sensitive.
- Less sensitive patients can be given a surface anaesthetic or be treated without anaesthetics. If no anaesthetic is administered, the patient should be informed that he/she might experience a sensation of warmth in the mucous area resulting from the germicidal effect of the laser. The sensation disappears after treatment has ended.

Preparation:

- The causes of fibroma are often irritation (jutting crowns or fillings, habits) and are to be determined clinically or anatomically and where possible removed.
- Clean the treatment site with a disinfectant such as H₂O₂ (3%), chlorhexamed.
- If, after complete ablation of a wide-based fibroma there is no tissue left for a histological test then a test excision should be made beforehand, if necessary.

Operating technique:

a) Stemmed fibroma

Stemmed fibroma are lifted by means of forceps or a tissue clamp and the basis localized. The excision is executed by means of the laser handpiece E, undermining the healthy tissue. The incision is made with a stroking movement whereby the pulse lines are superimposed along the desired excision line deeply and separated at the basis. The fibre (fibre insert 50/10) is brought into contact with the tissue.

Laser parameters:

Instrument: E 2055/2062, Size 50/10

	Energy (mJ)	Frequency (Hz)
Stemmed fibroma		
Excision	100-140 (180-250)* with contact	10-15
Wound treatment	130-190 (250-350)* 5 mm distance (defocused)	6-15

Footnote:

* the numbers in brackets denote the relevant setting of the device (please observe manual)

b.) Wide-based fibroma

Wide-based fibroma where, because of access, it is difficult to make an incision or where incision would take longer than the complete ablation can be ablated, defocussed, layer for layer starting at the surface. The handpiece is thereby defocussed in such a way that the ablating beam diameter is about 1/2 or 1/3 as big as the fibroma to be treated. The fibroma can thus be ablated with circular movements from the external contours to the centre. The excision should extend from the circumference to the depths down to healthy tissue. Clean the ablation site from time to time with a swab soaked in H₂O₂ or NaCl solution. If this technique is used, there is no patho-histologic material left for investigation after ablation. The onset of fibromatous changes adjacent to a fibroma can be removed prophylactically in this way.

Laser parameters:

Instrument: 2051/2060 or E 2055/2062 with size 50/10

	Energy (mJ)	Frequency (Hz)
Wide-based fibroma		
Excision	100-140 (180-250)* defocused	10-15
Wound treatment	130-190 (250-350)* defocused	6-15

Footnote:

* the numbers in brackets denote the relevant settings on the device. (please observe manual)

After execution of the excision, the wound is radiated at about 5 mm distance of the fibre (E 2055/2062, 50/10) to the surface, in order to dry and decontaminate the surface and, if necessary, at a shorter distance, to model the wound edges.

Post-treatment:

- Concerning the histological investigation, the patho-histologist should be informed about the excision biopsy by means of KEY Laser as the excision area can show a necrotic zone of about 40µm.
- A fibrinous membrane forms within the first week after the operation, the wound epithelizes within 2 weeks. For pain-sensitive patients, post-operative pain can be treated with an indifferent healing ointment.

Observations:

- To reduce warming effect and to have better control of the treatment depth, it is recommended to guide the working beam under constant movement.
- Penetration of the muscularis is to be avoided, as this can involve a painful post-operative healing.
- To avoid injuring the periphery, a wet wooden spatula or a swab can be placed behind the site to be separated.

Problems:

- Should ablation be hindered by heavy bleeding, an increase in suction is recommended.

Advantages:

- Minimum damage to adjacent soft tissue
- Suturing is often unnecessary thereby reducing functional losses caused by scarring
- No, or very little, post-operative pain
- Reduced post-operative swelling and discomfort
- see B 4.1

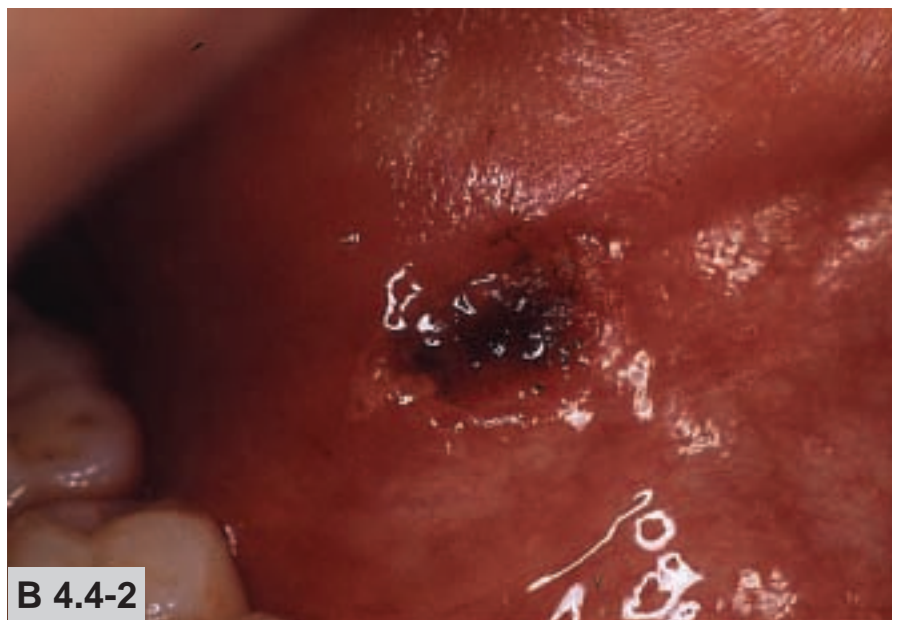
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- Bib. [6]
- Bib. [10]
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- Bib. [65]
- Bib. [69]
- Bib. [109]

Photographic documentation (Q [2]):

Fig. **B 4.4-1** stemmed fibroma on the buccal mucous membrane prior to laser excision with laser handpiece E 2055, fibre insert 50/10.

Fig. **B 4.4-2** Fibroma excision with 250 mJ*/10 Hz immediately after the operation. The patient, who had not received anaesthetics was immediately symptom-free. The centre was somewhat coagulated. The operation was performed without complications under good visual conditions.





B 4.5 Frenectomy

(according to Prof. Dr. Keller)

Indication:

- Correction of highly-inserted frenulum of the upper lip, frenulum of the tongue and buccal frenulum, extending too far into the alveola ridge or the marginal gingiva and influencing function, phonetics and denture fittings etc.

Contraindication:

- None known

Laser type:

- K·E·Y Laser

Instruments:

- Laser handpiece E 2055/2062 with fibre insert 50/10
- Surgical suction nozzle
- Moistened swab (or wet wooden spatula), if necessary
- Gauze or surgical forceps in the case of frenulum of the tongue

Anaesthetics:

- As a rule, local anaesthetics
- No anaesthetics if the patient is not pain-sensitive

Preparation:

- Cleaning of the treatment site

Operating technique:

- Depending on how the instrument can be positioned locally, either a vertical or a horizontal incision can be made.
- Frenulum of the lip
The upper and lower lips are parted as far as possible and the frenulum placed under tension. The fibre 50/10 is guided vertically at a short distance to the frenulum and the frenulum is cut along the desired line of incision. If an apical limit between marginal gingiva and oral mucosa is set in order to prevent a relapse, the tissue can be excised as far as the bone or the periosteum. In case of a diastema, the incision with fibre 50/10 is made right through the approximal space into the foramen incisivum (papilla incisiva). The fibre can be directed suprapariosteal and parallel to the tissue surface to avoid a lasering of the periosteum. If indicated, the oseous septum can be weakened by laser.

- Frenulum of the tongue
To tighten the frenulum of the tongue, the tongue is lifted with a swab or a retaining suture. Beginning at the middle of the frenulum, the frenulum is excised until the desired mobility has been reached. The side turned away from the laser can be protected from accidental laser radiation by placing a moistened swab behind it.

Laser parameters:

Instrument E 2055/2062 with fibre insert 50/10:

	Energy (mJ)	Frequency (Hz)
Frenectomy	100-140 (180 -250)*	6-15

Instrument 2051/2060:

	Energy (mJ)	Frequency (Hz)
Weakening of the oseous septum	250 with spray	4-10

Footnote:

- * the numbers in brackets denote the relevant settings of the device (please observe manual)

Post-treatment:

- Leave wounds open and apply an indifferent healing ointment or Kirkland dressing, or similar. In case of additional excision or osteotomy, care of the suture.
- Inform the patient that in the next few days there could be a slight burning sensation when eating. Prescribe a disinfectant mouth wash (e.g. chlorhexamed) to prevent a disturbance of wound healing.

Observations:

- Although bone and periosteum heal without complications after laser treatment, it should usually be observed that the incision is made supraperiosteal.
- The desired speed of treatment is controlled via the setting of pulse energy. A thermally-induced surface haemostasis is increased by a high frequency at lower energy density (defocused).

Problems:

- There is insufficient styptic effect in patients with blood coagulation disease.

Advantages:

- In most cases, no suturing is required
- Easier on the patient
- Time-saving because of less postoperative care
- Reduced scarring
- See B 4.1

Bibliography:

- Bib. [10]
Bib. [64]
Bib. [65]
Bib. [69]
Bib. [109]

Photographic documentation (Q [2]):

Fig. **B 4.5-1** Frenulum of the lower lip, highly-inserted, prior to laser frenectomy with laser hand-piece P 2056, fibre cyl..

Fig. **B 4.5-2** Situation immediately following laser frenectomy with 200 mJ*





B 4.6 Apicectomy

(according to Prof.Dr. C.P.Eduardo and Dr. S.Gouw-Soares)

Indication:

- Apicectomy on teeth with periapical lesion which had not responded to previous endodontic treatment or if retreatment is not recommended (e.g. presence of large cysts or extensive prosthetic restoration).
- Application of the KEY Laser to perform the osteotomy and the root resection.

Contra-indication:

- same as usual (esp. concerning general diseases).
- proximity of inferior nerve canal
- difficult access.
- root canals filled with metal pins down to the apex.

Laser type:

- K·E·Y Laser

Instruments, materials:

- Laser Contra-angle handpiece 2051/2060
- sterile water (for the KEY-Laser)
- small suction nozzle (flexible plastic cannula)
- Instruments for conventional surgical procedures (curettes, gauze etc.)
- saline irrigation syringes

Anaesthetics:

- Anesthesia is required by block injections and/or local infiltrations

Preparation:

- X-Ray(s) is necessary to determine the precise location of the periapical lesion
- Adjust spray volume of the laser handpiece.
- The area to be operated on, requires to be washed with a surface antiseptic like chlorhexidine.
- Firm incisions through the periosteum to the bone, as usual.
- A full thickness flap is elevated and the cortical bone defect exposed.

Operating technique:

- To improve the instrumentation access and visualization of the infected lesion and root apex the cortical bone is properly enlarged performing an osteotomy with the KEY Laser, in non contact mode with constant water spray irrigation.
- Laser parameters:

Instrument: Handpiece 2051/2060

	Energy	Repetition rate
Osteotomy	350 mJ	4 Hz

- The exposed periapical lesion is removed by means of a curette and should be sent to the laboratory for histopathological examination.
- After complete removal of infected tissue the root resection is done cutting off 2 to 3 mm of the apex with the KEY laser in non contact mode and with constant water spray irrigation.
- Laser parameters:

Instrument: Handpiece 2051/2060

	Energy	Repetition rate
Root resection	450 mJ	4-6 Hz

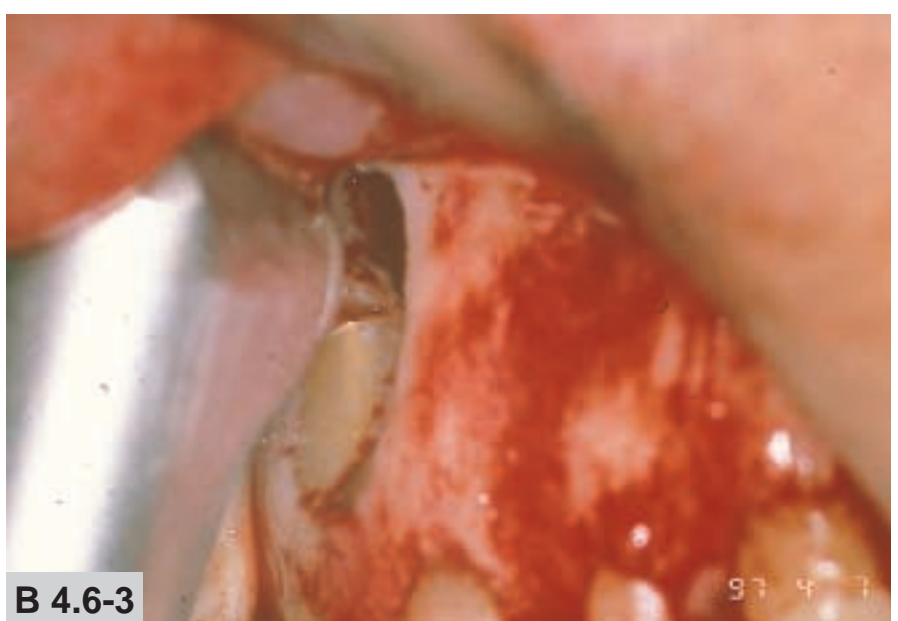
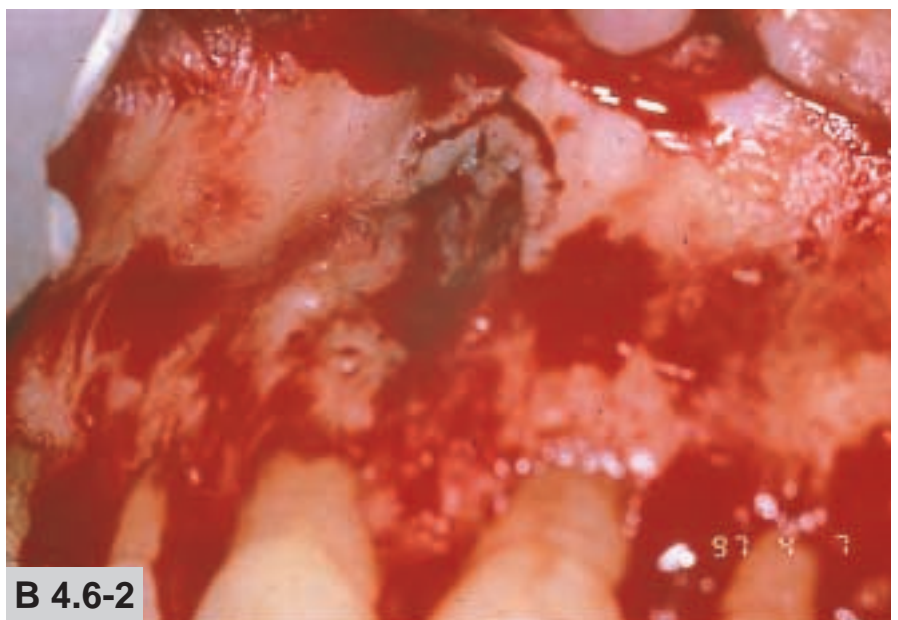
All the surgical bone site is inspected concerning complete removal of pathological tissue, well irrigated with saline solution and the flap repositioned and sutured in place. The postoperative care is given and periapical control radiograph is recorded before dismissing the patient.

Post-Treatment:

- The patient is required for suture removal one week after. Postoperative radiographs are recorded as usual.

Observations:

- none





Advantages:

- Less contamination of the surgical site by elimination of aerosol produced by high-speed handpiece drill in conventional surgery, during root resection.
- bacterial reduction of the surgical site.
- Absence of vibration discomfort
- Minimum damage to adjacent bone tissue during osteotomy and root resection.
- enlargement of the size of the bone defect is minimal.
- Post-operative pain is reduced and less swelling and discomfort observed.

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Photographic documentation:

- Fig. **B 4.6-1** : Radiographic at tooth 11 shows a large radiolucent image.
- Fig. **B 4.6-2** : Osteotomy with KEY Laser
- Fig. **B 4.6-3** : Root resection of tooth 11 with KEY Laser handpiece 2051
- Fig. **B 4.6-4** : Postoperative radiograph after 3 months
- Fig. **B 4.6-5** : Postoperative radiograph after 6 months.
- Fig. **B 4.6-6** : Postoperative radiograph after 12 months with significant bone regeneration



B 5 Periodontology

B 5.1 Curettage

(according to Prof.Dr. Keller)

Indication:

- removal of subgingival calculi in periodontal pockets with periodontitis by closed or open curettage.

Contraindication:

- None known

Laser type:

- K·E·Y Laser

Instruments, Materials:

- Laser handpiece P 2056/2061
- Large suction nozzle
- Swab soaked in 3% H₂O₂

Anaesthetics:

- While mechanical curettage requires anaesthetic, a laser curettage is more acceptable to the patient and often no anaesthetic is necessary.

Preparation:

- Thorough information concerning oral hygiene
- Conventional removal of supragingival plaque and tartar. Polishing of teeth.
- Cleaning of interdental spaces and, if necessary, opening of interdental spaces to improve the possibility to clean.
- Determination of probe depth
- Setting of water volume on laser handpiece
- Checking intactness, rotability and function of prism

Operating technique:

- To remove calculi, the fibre prism is placed, as far as possible, in a tangent under 10-20° to the tooth so that the calculi can be ablated directly in front of the prism.
- The prism is guided coronal to apical with slight pressure without tilting. In some cases, the presence of calculi is felt.
- According to the width of the prism, several parallel paths from coronal to apical are drawn and the affected area scanned.
- Where access to approximal areas is bad, the smaller prism is used with the same laser parameters.
- Water is used simultaneously and ablation is carried out under the following parameters.

Instrument: P 2056/2061

	Pulse energy (mJ)	Pulse frequency (Hz)
Calculi removal	70-120 (100-160)*	6-15

Footnote:

* the numbers in brackets denote the relevant settings for the device. Depending on the fibre, observe instructions for use.

Post-operative:

- Control that calculi removal is complete with hand instrument
- If necessary, the mucogingival marginal epithel is modelled by means of KEY Laser (see Chapter Surgery)
- Removal of ablated tissue and cleaning by means of swab
- Post-operative control of oral hygiene measures

Observations:

- The tangential working method results in a more homogeneous surface structure instead of ablating dentin in depth.

- Where larger calculi are ablated, there must be no hooking into the root surface. Larger concretions should be ablated by passing over them several times. When the fibre is drawn back, it is possible to check that the root surface is smooth.
- To avoid warming the tooth, the fibre is guided in a tangent as evenly and quickly (> 0.5 mm/sec) as possible without remaining on one spot for a longer time.
- Water should be used continuously to wash out the pocket and to avoid surface necrosis. Care should be given that the water flows as a rule up to the front horizontal position when working with a prism. If drainage is at water outlet or work is carried out using the prism in an upright position, then there is a danger of the water flow to the ablation site being prematurely interrupted.
- To avoid blood splattering, suction should be as near as possible to the ablation site
- Infected root cement is also ablated when laser is used. Differentiating between healthy cement is the responsibility of the attending dentist and is not dependent on the process, the same as with mechanical curettage.

Problems:

- None known

Advantages:

- Contact-free und traction-free curettage by means of KEY Laser light allows a mechanical and careful work method without stressing the loose tooth as is the case when executing a curettage with a scaler.
- Patients tolerate laser therapy better
- Good post-operative course with rapid healing and good gingiva adaption
- Efficient destruction of periodontal germs
- Granulation tissue on soft parts and bones can be removed efficiently

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B 5.2 Curettage with Detection

(as described by Prof.Dr. Reich)

Indication:

- Removal of subgingival calculi in periodontal pockets which have been affected by periodontitis, with open or closed curettage and using the detection function of the KEY Laser 1243.

Contraindication:

- None known

Laser type:

- K·E·Y Laser 1243

Instruments, Materials:

- Laser handpiece P 2061
- Large suction nozzle
- Swab soaked in disinfectants e.g. 3% H₂O₂, Chlorhexidin;

Anaesthesia :

- Although mechanical curettage usually requires anaesthesia, laser curettage is better accepted by the patients, so that local anaesthesia can sometimes be dispensed with.

Preparation:

- Accordingly to recommendations of societies of periodontology;
- Thorough instruction on oral hygiene;
- Conventional removal of supragingival plaque and tartar and polishing of the teeth;
- Cleaning of the interdental spaces and, if necessary, opening of occluded dental spaces, so that hygiene is assured;
- Determination of probe depth;
- Setting of water volume on laser hand piece P;
- Check that the prism is intact, can be rotated and functions well;
- Check that the detection is functioning correctly by holding the prism vertically in contact to the reference. The display number and the number on the reference should be the same to within ± 3 . When the prism is directed not onto a substance but onto the floor, the display should show "0". If necessary, retune (In accordance with the Instructions for Use, this must be at $22^{\circ}\text{C} \pm 2^{\circ}\text{C}$), or renew the prism.

- Probe the pocket with the detection function. If necessary, check the probe of the tartar by hand.
- Probe a tartar-free area of the root surface with the detection function and detect the current value.
- Select a threshold value, under which you wish the Feedback Mode to interrupt must interrupt the emission of laser pulses.

Operative technique:

- To remove tartar, the prism is set at 10-20 degrees, if at all possible tangential to the tooth; this is so that the tartar is removed directly in front of the tip of the prism.
- The prism is moved from the corona to the apex with a light touch and without tipping. No pressure should be applied, to avoid breaking the prism. During this time, the presence of calculi may be detected by hand.
- Depending on the breadth of the prism, several parallel tracks from the corona to the apex are traced, so that the affected area is covered.
- The smaller prism with the same laser parameters can be used for poorly accessible approximal areas.
- The ablation is carried out with simultaneous supply of water and with the following laser parameters.

Instrument: P 2061

	Pulse energy (mJ)	Pulse frequency (Hz)
Calculi Removal	70-120 (80-160)*	6-15

Footnote:

* The numbers in brackets give the settings for the apparatus. Check the Instructions for Use (depending on the fibre).

Follow-up:

- Check the complete removal of tartar with a hand instrument;
- If necessary, the peripheral mucogingival epithelium can be modelled with the KEY laser (see Chapter on Surgery);
- Remove the ablated tissue and clean with a swab and hand instruments;
- Postoperative control of the measures to ensure oral hygiene;

Comments:

- Working tangentially brings a more homogenous surface structure of the root, instead of transporting dentin into deeper levels.

- When large deposits are being ablated, hooking into the surface of the root should be avoided. Large deposits should be ablated by passing over them several times. When the fibre is drawn back, it is possible to check that the root surface is smooth.
- To avoid warming the tooth, the fibre should be guided tangentially and as evenly and rapidly ($> 0.5 \text{ mm/sec}$) as possible, without remaining on one spot for an extended period.
- Water should be supplied continuously, to rinse out the pocket and to avoid superficial necrosis. It should be noted that the water should normally flow forwards with the prism, almost up to the horizontal position. When water is removed at the efflux or when working "head-over" with the prism, there is the danger that the water supply at the ablation site can be prematurely interrupted.
- To avoid splashing blood, it is recommended to use the large nozzle, to bring this near to the ablation site and also to rinse the treated pocket copiously with water from a multifunctional syringe.
- Laser ablation also removes infected root cement. As with mechanical curettage, the differentiation from healthy cement is at the discretion of the dentist and is not determined by the process.
- While material or soft tissue is being removed, it can happen that fluorescent particles or coagulated blood sticks to the point of the fibre and that the detection function reacts to this. This is particularly the case when the fibre tip is surrounded by little water. In the Feedback Mode this does not lead to the emission of pulses being interrupted, but that this is practically exclusively dependent on activating the foot starter, as in the Standard Treatment Mode. The tip of the fibre should be removed from the pocket, to check if the current value falls to "0". If this is not the case, the fibre tip should be cleaned or renewed.
- Changing instruments can lead to water getting inside the instrument and wetting the optics. Specific causes of this can include rapid removal of the instrument or inadequate drying of the instrument's coupling before it is connected. This should be avoided, as it can lead to disturbance function, which can for example be noted in the scatter in the values detected. It may be necessary to dry or to clean or to service the instrument.
- Foreign light sources may illuminate the fibre tip and thus disturb the detection system. With direct illumination this can be seen in scatter in the current values. It may become necessary to evaluate the effect during use and to remove the cause (for instance by switching out light which is disturbing the measurements).

- The detection can react to some ceramic crowns, inlays or filling materials, if these fluoresce.

Problems:

- None known

Advantages:

- Curettage with KEY laser light is a low contact and draught free process, which permits mechanically sensitive work, without stressing the loosened tooth as is the case with curettage with scalers.
- Sparing the tissue and reduction of the number of released pulses by interrupting their release in the Feedback Mode.
- Good acceptance by the patients of laser treatment.
- Good postoperative course with rapid healing and good adaptation of the gingiva.
- Parodontal bacteria are efficiently killed.
- Granulation tissue in soft tissue and bones can be efficiently removed.

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C 1 Conservative therapy

-no cases on record-

C 2 Endodontics

C 2.1 Acute coronal pulpitis

Case report Dr. Lutz

Initial findings:

The patient (male, 45 years) was referred for treatment for acute, severe pulpitis. Four weeks previously, crown stump treatment had been carried out on 3/6 and 3/7 and since then the pain had increased.

Laser type:

- K·E·Y Laser

Instruments:

- Coronaflex (KaVo)
- Motor instrument
- Laser contra angle handpiece 2051
- Laser handpiece E 2055 with fibre insert 30/28

Anaesthetics:

In spite of double anaesthetic blocking with the addition of adrenaline, it was not possible to eliminate sensibility. An attempt was made to open and excise the pulp with a rotating instrument but this was not tolerated by the patient.

Preparation:

The crowns on 3/6 and 3/7 were removed with great care and consideration for the patient and without damage with the help of Coronaflex. With a rotating motor instrument, the cavities were widened as far as the patient could tolerate up to the vicinity of the pulp.

Operating technique:

- With the laser contra angle handpiece 2051 cavity treatment near the pulp and opening were carried out at 300mJ/4Hz with spray.
- Excavation of the total coronal pulp was likewise carried out with the laser contra angle handpiece at 250 mJ/15 Hz without spray and with focussed beam. Thereby, the excavation of pulp tissue, as far as access allowed, was continued right into the canal entrance.
- Using the laser contra angle handpiece E2055 and fibre insert 30/28 (smallest available fibre size) the nerve was extirpated with an instrument setting of 250 mJ/15 Hz at the distal canal by a further 3-4 mm and at the mesio-lingual canals by a further 2 mm.
- After the pain sensibility from the treatment had subsided, treatment was suspended for two minutes. Then the remaining canal pulp was removed by means of an extirpation needle and the canals conventionally prepared up to ISO 40 and attended to endodontically per laser. A provisional filling of calcium hydroxide was made.

Post-operative:

- One day after the operation, the patient was free of pain. The filling was removed and the tooth treated endodontically.

Observations:

- The above-mentioned parameters for treatment close to pulp, excavation of coronal pulp and extirpation into the canal entrances were selected in order to cause as little stress as possible to the patient and to free him from his pulpitis as quickly as possible. The selection of parameters was made especially considering that the vitality of the tooth could no longer be saved. If the vitality of the tooth is to be saved then other parameters are selected.

Problems:

- At the time of writing, the post-operative course had been recorded over a period of six months without complications.

Advantages:

- In spite of the failure of a double blocking, which in the case of acute inflammation of coronal pulp can be observed, it was possible to carry out the treatment in a considerably pain-reduced condition for the patient and to make an endodontic treatment tolerable for him.
- For the attending dentist and the assistant the atmosphere during the operation was less tense and offered an improved opportunity to carry out treatment.
- Without the use of laser, it would not have been possible to carry out immediate endodontic treatment followed by a calcium hydroxide filling in the same session. It was not necessary to make a devitalising filling on the basis of arsenic, formaldehyde or similar substances (with the known side-effects).

C 3 Surgery

Operating technique:

The aphtha was lasered without spray, beginning at the outside edge. During this, the laser was in slight contact with the healthy region on the periphery. The beam was guided in concentric circles from the exterior to the interior whereby the pulses overlapped one another by almost a third in order to cover the whole area of the defect. The laser beam was defocused so that the ablation threshold of the tissue was slightly exceeded. This resulted in the tissue being dehydrated. A whitish surface formed and the most exterior layer of tissue deepithelized. The treatment lasted approximately 20-40 seconds. The suction nozzle was kept near the treatment site to remove ablated tissue.

Laser parameter:

Instrument 2051

C 3.1 Aphthae (herpes, decubitus)**Case report Dr. Lutz**

Initial findings:

The patient (female, 39) was suffering from painful aphthae on the cheeks and in the lower lip region. Fortunately, the formation was in the early stages (2 days following lesion, wound surface had not yet healed). After explaining alternative treatment, the following therapy was carried out at the wish of the patient:

Laser type:

- K·E·Y Laser

Instruments:

- Laser contra angle handpiece 2051
- Large suction nozzle

Anaesthetics:

No anaesthetics in the cheek area. As the patient was extremely pain-sensitive, a surface anaesthetic was applied to the lip.

Preparation:

The patient was informed that she might feel a sensation of warmth in the region of the lip during laser treatment.

	Energy (mJ)	Frequency (Hz)
Aphthae	60-120	1-4
	defocused	
	near ablation threshold	

Post-treatment:

- None

Observations:

- The patient was informed about the whitish changes to the aphthae and told that they do not disappear spontaneously but usually within 8-10 days.
- A focused application was not used as the lesions would have been unnecessarily irritated.
- Suction was applied as near to the treatment site as possible in order to prevent a transfection from ablated viruses.

Problems:

- None

Advantages:

- The initial pain and tension caused by the aphthae decreased already during treatment.
- The aphthae of the lip re-occured post-operatively compared with previous attacks relatively late (not until after 15 months) and did not re-occur after renewed treatment. There was no further formation of aphthae in the region of the mouth or the cheeks.
- Simple operating technique.



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E 1 Overview of parameters

	Pulse energy mJ	Pulse frequency Hz		Pulse energy mJ	Pulse frequency Hz		Pulse energy mJ	Pulse frequency Hz
B 2 Preservative therapy			B 3 Endodontics			Instrument 2051/2060 or E 2055/2062, 50/10:		
B 2.1 Instrument 2051/2060 Carious dentin	150-250	2	B 3.1 Instrument E 2055/2062: Root canal disinfection	50 (120-160)*	6-15	Wide-based fibroma		
Healthy dentin	200-250	2				Excision	100-140 (180-250)* defocused	10-15
Enamel	300-400	2-3				Wound treatment	130-190 (250-350)* defocused	6-15
B 2.2 Instrument 2051/2060 Preparation near to the pulp	150-250	1, max. 2	B 4 Surgery			B 4.5 Instrument E 2055/2062 with fibre insert 50/10:		
B 2.3 Instrument 2051/2060 Base filling cement Root-canal filling material	200-300	1, max. 2	B 4.1 Instrument 2051/2060: Incision, excision	60-300	4-10 max. 15	Frenectomy	100-140 (180-250)*	6-15
Composite	400	1-2	B 4.2 Instrument 2051/2060: Ablation of extended areas of oral mucosa	60-350 (defocused)	1-10	Instrument 2051/2060: Weakening of oseous septum	250 with spray	4-10
B 2.4 Instrument 2051/2060 Dentin conditioning	60-300 (defocused ablative, 40 mJ/mm ²)	2-6	B 4.3 Instrument E 2055/2062 with fibre insert 50/10			B 5 Periodontology		
Laser drying	60-100 (defocused subablative)	2-6	Implant exposure incision	100-140 (180-250)*	10-15	B 5.1 Instrument P 2056/2061:		
B 2.5 Instrument 2051/2060 Dentin conditioning	350 (defocused ablative, 200 mJ/mm ²)	2-10	Instrument 2051/2060 Implant exposure modelling	160-250	4-10	Calculi removal	70-120 (100-160)*	6-15
Laser drying	60-100 (defocused subablative)	2-6	B 4.4 Instrument E 2055/2062 with 50/10			Footnote: * the numbers in brackets denote the relevant setting for the device (please observe manual)		
B 2.6 Instrument 2051/2060 Fissure conditioning	120-220	2	Stemmed fibroma Excision in contact	100-140 (180-250)*	10-15			
			Wound treatment at 5 mm distance	130-190 (250-350, defocused)	6-15			

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