Fundamentals of

LASER DENTISTRY

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Foreword
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Dedicated to

My father Dr BS Johar, who has been my inspiration in dentistry and in life.

My mother Mrs Paramjit Johar, who taught me the values of integrity, sincerity and hard work.

My best friend and wife, Harleen Johar, for her unconditional support and for making my life more meaningful.

My sisters, Mrs Jasmine Suri and Mrs Mansha Sood, for always being there when I needed them.

Foreword

It was ten years ago that I first started using three different wavelengths of Dental Lasers. With no training available in India at that time, I had to travel to different countries, wherever someone was willing to teach me. A few years later, SOLA Academy in Vienna was started and I went through my Masters Degree Certificate.

I was then determined to start an academy in India to popularize and help spread the knowledge of Lasers. Kirpa was amongst the first few to join and successfully complete the Masters.

Today, he is keeping alive my dream of spreading the light of lasers in our fraternity and the result is this simple guide to using lasers in the Dental Clinic. One can feel the sincerity with which he has compiled and brought forth this book.

I do hope that the Dentists will find this book a must for guiding them for a better treatment plan.

I wish him all the success.

Naresh Thukral BDS
Masters Degree Certificate Laser Dentistry (Vienna)
Founder President, SOLA India

Preface

Fundamentals of Laser Dentistry has been conceptualized and written with the aim to make the study of lasers both exciting and easy to understand. There is immense potential for this wonderful tool, especially in oral laser application. Today, there is tremendous change and constant advancement and I believe that laser is one key component that can revolutionize dental treatment and practice.

From the beginning of my laser study and throughout my masters program, I felt the need for a comprehensive book covering the basic concepts of Laser-assisted Dentistry, which ranged from basics to clinical practice. After careful thought, I tried to pen down a single book with all the key topics of laser physics, different wavelengths and its clinical applications. This textbook has been prepared in a manner that is easy to understand. Numerous diagrams, charts, photographs and schematic illustrations have been included to further enhance the understanding of the subject.

I have recently launched Laser Dentistry Research and Review (*www.ldrr.org*) in lieu for the need for a platform for the dental fraternity to access and exchange the latest techniques and procedures in the field of laser dentistry.

This book aims to be a concise but precise guide to Laser-assisted Dentistry. Laser has made considerable forays into routine dental practice such as cavity cutting, endodontics and periodontal therapy; laser-assisted cosmetic procedures such as teeth whitening and crown lengthening, to name some of the procedures are common. This is further supported by studies that validate the use of hard tissue and soft tissue laser that enhances conventional therapy and plays a significant role in the delivery of the twenty-first century health care. The trend is growing steadily. The noninvasive nature of lasers makes it more favorable for the patient. Limited postoperative pain, faster recovery, bloodless and sutureless procedures are other advantages of using laser resulting in better patient compliance and satisfaction.

An attempt has been made to bring about a textbook that is easy to understand and comprehend. This journey has been a truly humbling experience. I fervently desire that this work will help those who wish to pursue laser dentistry, those who look forward to upgrade their current practice and for those who have just started to practice laser dentistry, as a ready-reference.

I will be glad if the dental fraternity, students and peers find it useful.

Kirpa Johar

Acknowledgments

It is with sincere appreciation and thanks that I would like to acknowledge the invaluable inputs and help received from my peers and associates to complete this book.

I would first like to extend my gratitude to Jaypee Brothers Medical Publishers (P) Ltd, New Delhi for giving me this opportunity. Writing this book has been one of my most cherished aspirations and it would not have been possible without their faith and encouragement.

I am most grateful to Dr KG Ghorpade, who has been my guide and the source of valuable insight on the various aspects of book writing. Writing on various topics often requires a collective effort. I appreciate the invaluable support I have received from Dr Vikram, Director, Vikram Perfect Center for Advanced, Dermatology, Cosmetic Surgery and Dentistry (Mysore); Dr Anita Nitin and Dr Anil SR of Vikram Perfect (Mysore), in the form of case studies and for sharing their exceptional work with the readers.

I would like to extend my regards to Mrs Shanta Chandrashekar for proofreading the manuscript and Mr Ravi and his team at Omega Lasertech for typing the manuscript and the tables with patience and sitting through the endless hours of corrections with me. I am grateful to Mr Babu for clerical assistance.

The textbook is incomplete without illustrations and diagrams. Web pepper has let me its expertise in this regard, my heartfelt thanks to *www.webpepper.in*

Dr Vinod has been indispensible with his help on reference work. Also, I would like to mention Mr B Sabrish of Studio Bangalore, Bengaluru, Karnataka for the very professional photography of the laser instruments.

I would like to sincerely thank Dr Naresh Thukral, Dr Anil C Shah, Dr Mohan Vakade, Dr Vivek Hegde and Dr Sanjay Jain of Society of Oral Laser Application (SOLA), India. They have been a source of constant inspiration and a guiding force in my journey of Laser Dentistry. I would also like to thank Dr Moritz and Dr Beer of SOLA International for introducing me to the fascinating world of Laser Dentistry.

I am extremely thankful to Mr Peter Rowland, Vice President, Biolase; Mr Aneja of Fatona; Mr Ashish Mittal, Country Manager Sirona, India. Confident Group, Marketing Partner for ARC and Syneron Laser Systems, AMD Lasers-Picasso and Deka Lasers have graciously allowed me to use the photographs of their laser equipments. I would also like to acknowledge the other laser companies whose equipment, photographs have been used for illustration purposes.

My special thanks goes to Dr Afshan Shoiab, who has assisted me on various laser dental cases that gave her the basic knowledge of lasers. This proved to be a boon as she gave constructive inputs to the content, Dr Reena Joseph who has offered valuable suggestions and contributed towards the final compilation of the manuscript and Dr Amogha Kannan, a part-time writer, who contributed with the final draft of the textbook and in compiling case photographs and illustrations.

Last but not least, I would like to convey my gratitude to all my wellwishers who have helped me in various ways make this work a realty.

Contents

CHAPTER

1

Basic Physics and Concepts of Lasers used in Dentistry

INTRODUCTION

The word laser represents an elegant Acronym as "Light Amplification by Stimulated Emission of Radiation". It was demonstrated for the first time in 1960 by Maiman.

Typical lasers, which emits in the visible and the adjacent areas of the UV and IR wavelengths comprise of a large number of Individual laser materials and laser oscillator setups working in the continuous wave or pulsed mode.

The development and application of lasers, emitting rather collimated or more or less intensive beams of narrow bandwidth coherent light, in association with optical and electro-optical components, has been recognized as a new field of optical science called photonics, comprising of aspects of quantum optics, electro-optics and linear and non-linear optics.

PROPERTIES OF LIGHT

Light is a form of Electromagnetic energy that travels in waves at constant velocity. The basic unit of this radiant energy is called a Photon or a particle of light. A wave of photons can be defined by two basic properties:

Amplitude: Defined as total height of the wave oscillation from the top of the peak to the bottom. It is the measurement of the energy in the wave. The unit of energy is Joule.

Wavelength: It is the distance between any two corresponding points on the wave. It is the measurement of physical size measured in Meters.

Frequency: The measurement of a number of wave oscillation per second. It is inversely proportional to the wavelength, shorter the frequency, higher the wavelength.

Ordinary light is usually diffuse, not focused, e.g. light produced by a table lamp is a warm white glow. It is polychromatic, noncollimated and incoherent type.

Real light waves are circumscribed and hence subject to diffraction, i.e. the distribution of amplitude over the cross section varies during propagation.

In case of confined light distribution called a beam, the direction of propagation is not sharply defined but is distributed over a certain range of vectors.

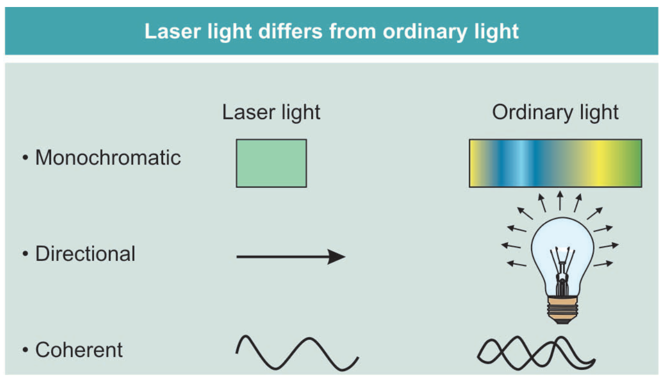
Light produced by laser has opposite properties. It is monochromatic, coherent and collimated type.

Laser light has the property of one specific color which is finely focused called **Monochromatism.** The precision of the monochromatic beam is due to additional characteristics: collimation and coherency.

Collimation refers to the beam having specific spatial boundaries which ensures that there is a constant beam size and shape that is emitted from the laser unit.

Coherency refers to unique property of lasers. The light waves are a specific form of electromagnetic energy that are physically identical. They are all in phase with one another, i.e. they have identical amplitude and identical frequency **(Table 1.1).**

Table 1.1



FUNCTION OF LASER INVOLVING OPTICAL CONCEPTS

Interaction Between Light and Matter

Threefold interaction between light and matter has three important features: Absorption, spontaneous emission and stimulated emission.

Absorption (Fig. 1.1) is the process indicated by the transfer of an electron from energy level E_1 to E_2.

Spontaneous emission (Fig. 1.2) is the mechanism for the reciprocal electronic transition E_2 to E_1, which is the result of typical radiative decay of excited electronic states of atoms or molecules.

It is comparable to radioactive decay of excited or unstable nuclear states.

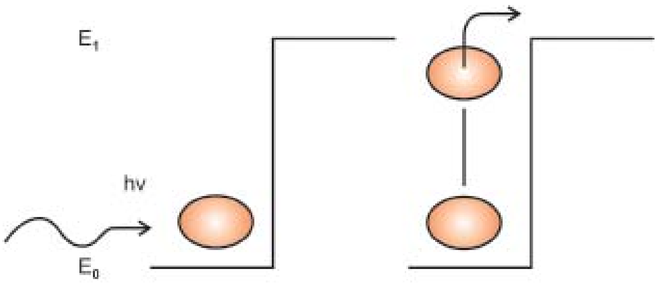


Fig. 1.1: Absorption

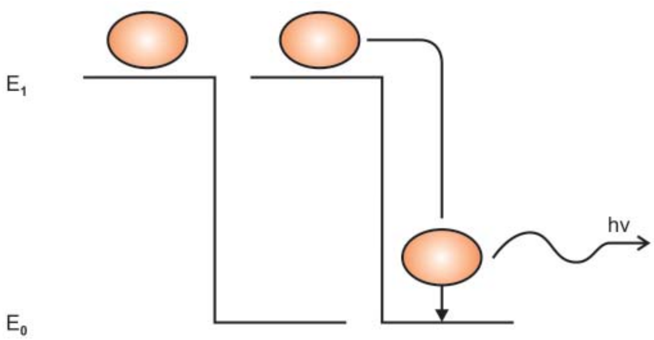


Fig. 1.2: Spontaneous emission

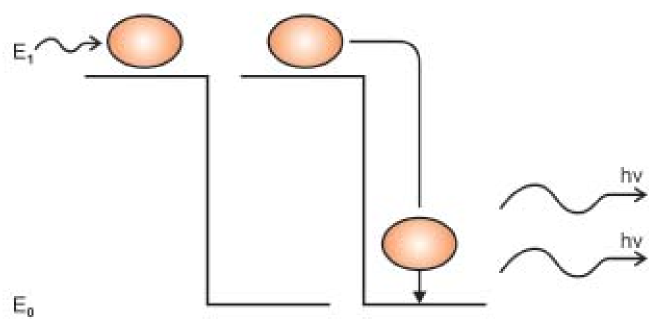


Fig. 1.3: Stimulated emission

Stimulated emission (Fig. 1.3) represents the decay mechanism, that can only occur if a photon interacts with an atom in the excited state causing the emission of a second, identical photon.

The higher the energy of a photon, the shorter the wavelength. All dental lasers emit either a visible light beam or an invisible infrared light beam in the portion of the nonionizing spectrum called thermal radiation.

Basic Scheme of a Laser

The basic scheme **(Figs 1.4A and B)** of each laser comprises of laser medium, which is excited by an

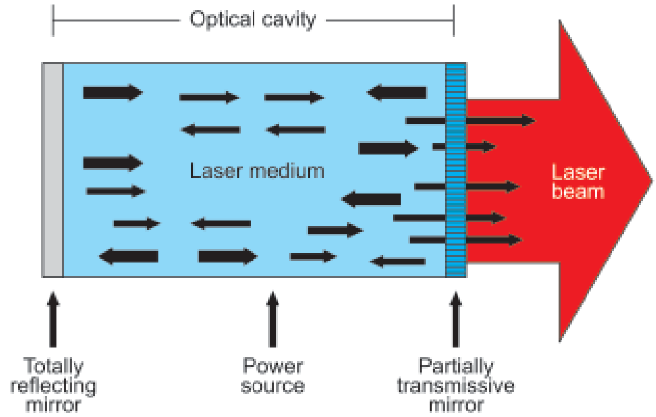


Fig. 1.4A: Basic scheme of laser

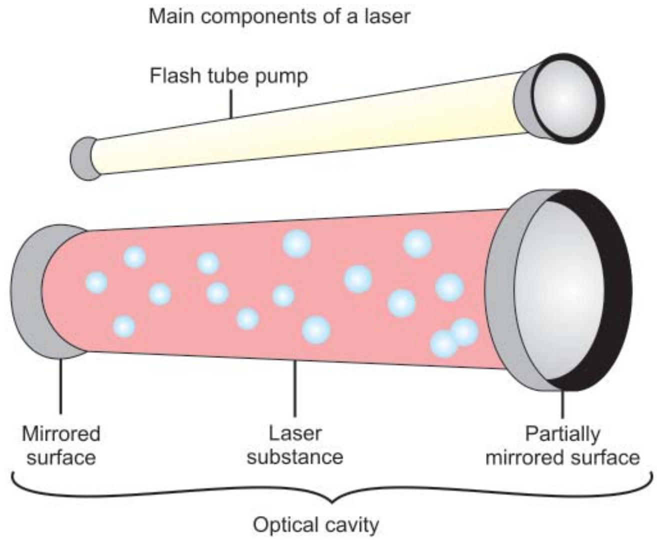


Fig. 1.4B: Main components of a laser

external source. Light can travel to and fro many times along a defined axis by being repeatedly reflected by mirrors of different reflection [R] forming an **optical oscillator or Resonator** (also called cavity). The laser oscillator stores light via multiple reflection of its mirrors, but also emits light through the partially transmitting out-coupling mirror. The laser light oscillates and is amplified during each pass through laser medium. If the resonator is filled with radiation at one instant of time, it emits a beam.

Population Inversion

Population inversion is a situation in which the occupation of a higher energy level is greater than the occupation of a certain lower level under nonlinear optical conditions, so that net amplification takes place.

This inversion cannot be achieved by strong pumping of two-level system because the probabilities of absorption and stimulated emission are the same. Hence three-level and four level systems are required in order to realize inversion and hence amplification.

For lasing, the upper laser level should have a higher population density. Pumping always has to be done at a shorter wavelength than the laser activity.

In a three-level system **(Fig. 1.5)**, the atoms or molecules are raised from ground level O to level 2 by a pumping mechanism. If the material is such that after reaching level 2 decays rapidly in a radiative or non-radiative manner to the longer life time level 1, population inversion can be obtained between level 2 and level 1.

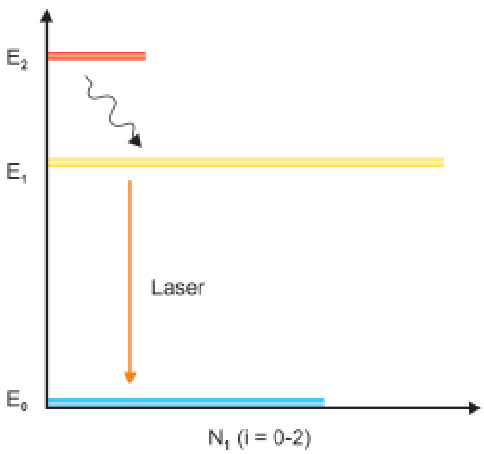


Fig. 1.5: Three level system

In a four level laser **(Fig. 1.6)**, atoms are raised from ground level 0 to level 3. If the atoms or molecules decay rapidly to level 2, it should remain as long as possible so that population inversion can be obtained accordingly between levels 2 and 1. Once oscillation starts, the atoms will be transferred to level 1 via stimulated emission for continuous wave operation. In a four level laser it is necessary that the transition 1 → 0 should be ultrafast to keep level 1 at a lower population than level 2.

Gaussian Beam and Laser Resonator

Gaussian beam represents the shape of a laterally confined wave which is easily treated theoretically as well as practically. Its Amplitude [E] as well as its Intensity [I] profile distribution follow a Gaussian bell

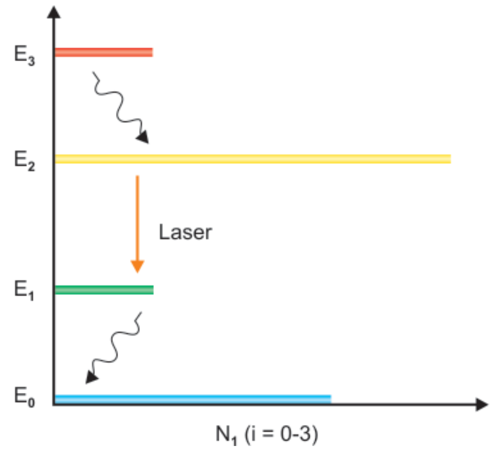


Fig. 1.6: Four level system

curve, which in principle extends to Infinity, although with a very rapid loss of height.

Laser resonators are the active medium contained within an optical enclosure in which the laser light oscillates and is amplified during each pass through the laser medium.

For the beam of laser quality to be generated adequate resonator mirrors have to be put in place in the medium.

Stimulated emission, like that of the laser amplification mechanism, requires the interaction of light with an Inverted laser medium. All the resonator configurations shown are symmetric or half symmetric and stable.

The common stable resonator configuration are:

- Coplanar (plane mirrors)
- Over-confocal (large radii of curvature)
- Confocal
- Spherical (concentric)
- Hemi-spheric (half concentric).

Beam Delivery System

The coherent collimated beam of light, must be delivered to the target tissue in a precise manner. Beam is delivered in three ways–fixed beam path, articulated arm path and the fiber.

Two delivery systems are used in dental lasers. One is a flexible hollow wave guide or tube that has interior mirror finish. The laser energy is reflected along this tube and exists through a hand piece, with the beam striking the tissue in a non-contact fashion.

The second delivery system is a glass fiberoptic scale. The fiber fits snugly into a hand piece with the bare end protruding or with an attached glass-like tip. This fiber system can be used in contact or non-contact mode.

Emission Modes

Contact mode: In this type the distal end of an optic fiber is placed in direct contact of the target tissue.

Non-contact mode: The hand piece is held away from the tissue and a guide is provided to focus the beam at the desired target tissue.

The laser device can emit the light energy in one of three basic modes. The first is continuous wave, the second is gated pulse mode and the third is free running pulsed mode.

In continuous wave mode the beam is emitted at constant power continuously by continuous pumping. The average power is equal to the peak power.

In gated pulse mode there are periodic alternations of the laser energy which is achieved either by opening or closing of a mechanical shutter in front of the beam path of a continuous wave emission. The duration of this type of laser is normally as small as a few milli seconds.

Free running pulsed mode is unique. The pulses are delivered with high peak power. Large peak energies of laser light are emitted for an extremely short time period.

The important principle of any laser emission mode is that the light energy strikes the tissue for a certain time, producing a thermal interaction.

LASER TISSUE INTERACTIONS

The light energy from a laser can have four different interactions with the target tissue and these interactions depend on the optical properties of that tissue and the wavelength used.

The first interaction is **reflection (Fig. 1.7A)** in which the beam redirects itself off the tissue surface without any effect on the target tissue.

The second interaction is **absorption (Fig. 1.7B)** of the laser energy by the intended target tissue.

The third interaction is **transmission (Fig. 1.7C)** of the laser energy directly through the tissue, with no effect on the target tissue.

The fourth interaction is **scattering (Fig. 1.7D)** of the laser light, weakening the energy and possibly producing no useful biologic effect.

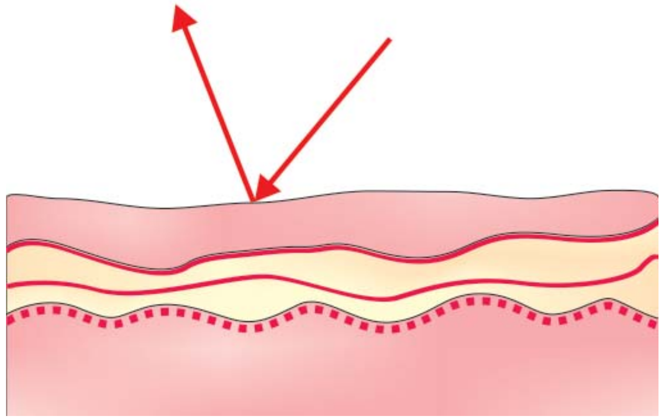


Fig. 1.7A: Reflection of laser by target tissue

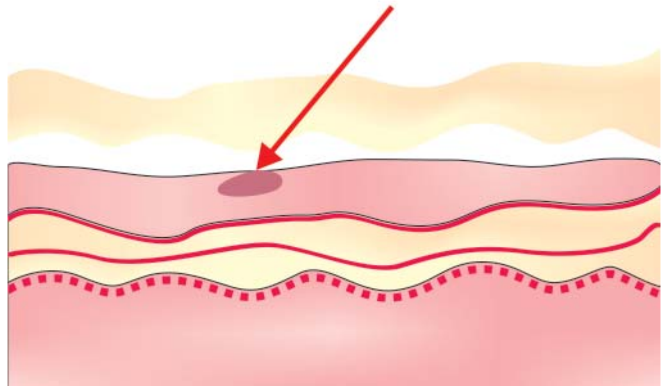


Fig. 1.7B: Absorption of laser by target tissue

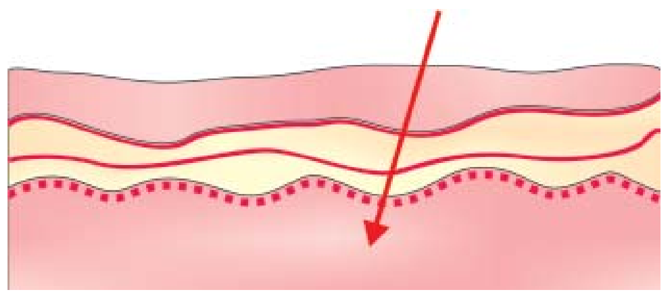


Fig. 1.7C: Transmission of laser by target tissue

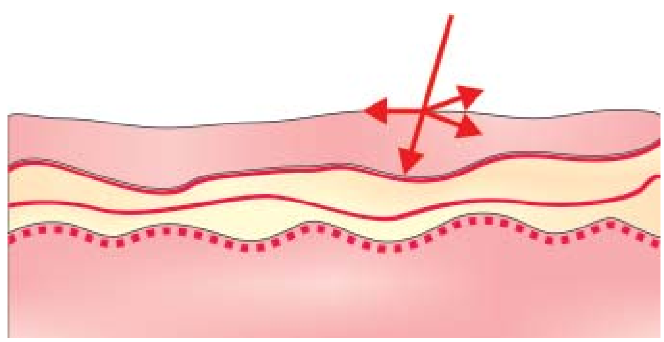


Fig. 1.7D: Scattering of laser by target tissue

The primary and beneficial effect of laser energy is absorption of the laser light by intended biological tissue. Dental laser surgery optimizes these photo-biologic effects. Incisions and excisions accompanying precision and hemostasis, is one of the advantages of lasers. Besides photo thermal effects, lasers also have photo-chemical and photo-acoustic effects.

Effects of Temperature on Target Tissue

The thermal effect of laser energy on soft tissue primarily revolves around the water content of the tissue and the temperature rise of the tissue **(Table 1.2)**.

Table 1.2

Tissue temperature [°C]	Observed effect
37-50	Hyperthermia
60	Coagulation, protein denaturation
70-90	Welding of tissue
110-150	Vaporization
>200	Carbonization

LASER MEDIA

Gas Lasers

Laser medium → Gas

Gases are contained within appropriate tubes, which are sealed either by special windows or by di-electric mirrors, e.g. HeNe laser, CO_2 laser, Excimer laser, Ion laser.

Dye Lasers

Laser medium → Liquid suspension

Liquid laser media are primarily dyes dissolved in alcoholic solutions. The most prominent and efficient dye is Rhodamine 6G.

Semi-conductor—Diode Lasers

Laser medium → Doped semiconductor crystal

It is based on uniting laser and host properties, thereby containing the highest density of energy state to be potentially inverted (allowing highest amplifications) **(Fig. 1.8)**.

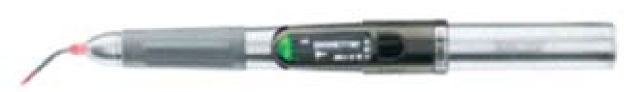


Fig. 1.8: Diode machine

Solid-state Lasers

Laser medium → Doped crystals

They consist of a host medium with laser ions or molecules embedded in it. The medium chosen is a crystal because it may offer optimum heat transportation properties. The doping ions for solid state lasers are taken out of two groups in the periodic system: either rare earths (such as Nd^{3+}, Yr, Ho, Er) or transitional metals (such as Cr^{2+}, Cr^{3+}, Cr^{4+}, Ti^{3+}).

E.g.:- Nd:YAG (Neodymium: Yttrium, Aluminum Garnet), Er:YAG (Erbium: Yttrium, Aluminum Garnet), Er.Cr: YSGG (Erbium, Cromium: Yttrium Scandium Gadolinium Garnet), Ho: YAG (Holinium: Yttrium, Aluminum Garnet), KTP.

PUMPING METHODS AND SCHEMES

There are a wide range of options for pumping, in order to transfer energy into the laser medium.

The following processes may be employed:

- Optical pumping by strong lamps or lasers.
- Electric pumping by gas discharges.
- Chemical pumping by reactions yielding excited molecules.
- Impact pumping by inelastic collisions between partners.
- Electronic pumping by diffusion of carriers in semi-conductors.
- Pumping by acceleration of electrons (free electron laser).

Electronic pumping deals with the semiconductor laser. This is the best laser to date with respect to effectivity (>50%), cost and maintenance. It is the cheapest source of monochromatic light of substantial power and is excellent when used for optical pumping.

LASER CONCEPTS

The following are brief descriptions of the available laser devices that have dental applications. The laser is named according to its active medium, wavelength, delivery system, emission modes, tissue absorption and clinical applications.

Excimer Laser

Excimer laser is a special gas laser based on unstable molecules called Excimer (Excited Dimers). They exist only in the excited state for nanoseconds which is enough for long pulsed laser action.

The emitted beam has the shape of a window. This type of laser represents the most important source of short-wave length radiation.

Wave Lengths

F_2	158 nm
ArF	193 nm
KrF	249 nm
XeCl	308 nm
XeF	351 nm

Medium

Typically mixture of rare gas (e.g. Kr) 5-10%
Halogenide (e.g. F_2) 0.1-0.5%
Buffer gas (e.g. He/Ne)
Pumping → Plasma discharge
Operation mode → Pulsed

Dye Lasers

Wavelengths → 500-800 nm (Depending on dye suspension).
Medium → Liquid suspension of dye.
Pumping → Flash lamp (other laser sources).

Argon Ion Laser

Argon lasers have an active medium of Argon gas that is fiber optically delivered in continuous wave and gated pulse modes. The laser has two emission wavelengths and both are visible to the human eye: 488 nm blue in color and 514 mm blue green in color is very expensive to purchase and to maintain.

Uses

- Polymerization of resin in light cured composites materials.
- Hemostasis.
- Treatment of acute inflammatory periodontal disease.
- Aid in caries detection.

CO_2 Laser

The CO_2 laser is one of the oldest laser. It is a gas-active medium that must be delivered through a hollow tube-like wave-guide in continuous or gated pulse mode. It is well absorbed by water and has a shallow depth of penetration into tissue and effective in soft tissue excision. It is especially useful in cutting dense fibrous tissue.

The CO_2 laser cannot be delivered in an optic fiber. Instead, a hollow wave-guide with a hand piece is used. Large lesions can be treated easily using a simple back and forth motion. The loss of tactile sensation is a disadvantage for the surgeon.

Wavelength

9.6 μm IR
10.5 μm IR

Medium

mixture of CO_2, N_2, He ratio depending on the wavelength
typically CO_2: N_2: He = 0.8: 1:7
Pumping → Plasma discharge
Operation mode → Cw, pulsed.

Semi-conductor Lasers/Diode Lasers

It comprises of solid active medium that uses a combination of aluminum, gallium and arsenide to change electric energy into light energy.

The available wavelength for dental use range from about 800 to 980 nm **(Fig. 1.9A and B)**.

Delivers laser energy fiber optically in continuous wave and gated - pulsed mode.

Fig. 1.9A: Example of diode laser

Fig. 1.9B: Diode hand piece

Fig. 1.9C: Diode laser tip

Advantages of diode lasers are:

- Excellent hemostasis.
- Soft tissue surgery can be performed effectively, as it is poorly absorbed by tooth structure.
- Indicated for cutting and coagulating gingiva and mucosa and for soft tissue curettage or debridement.
- Flexibility of the delivery system to target issues.
- Laser units are portable, compact and are lowest priced laser currently available.

Wavelength

Variation from VIS down to IR is commonly between 860 to 980 nm for surgery.

Medium

In Ga As - Indium Gallium Arsenide typically for Infrared diodes.

Heterostructure set up (i.e. multiple buyers of different doped semiconductor crystals).

Pumping → Most commonly by injection of carriers.

Operation mode → CW, pulsed.

Solid State Laser

Nd:YAG, Ho: YAG, Er: YAG and Er, Cr: YSGG.

Nd:YAG

- The most important is the Neo-dymium laser based on the rare - earth ion Nd.
- This ion can be incorporated into different host materials, the most important ones being YAG (Yttrium, aluminum garnet) and several glasses.
- YAG offers favorable mechanical and thermo-optical properties allowing its use for CW and pulsed lasers, even at high power.
- Most commercial laser emit the wavelength l064 nm corresponding to transition of energy levels.
- Excitation is achieved by optical pumping into broad energy bands followed by radiation.
- It consists of a hollow cavity with gold-coated internal surfaces revealing an elliptical cross section.
- In medicine, this laser has been used for long time, taking advantage of its greater depth of penetration into the tissue and dispersion in tissue as a result of scattering.

- Coagulation stops bleeding effectively and immediately after the incision.
- Another advantage, in comparison with the CO_2 laser, is the propagation through silica fibers allowing for endoscopic use or for fibers to be inserted in root canals, etc.

Erbium and Erbium-Chromium Lasers

- In crystalline Er-lasers, the host crystals are usually YAG (Yttrium Aluminum Garnet), YALO (Yttrium Aluminum Oxide), YSGG (Yttrium Scandium Gadolinium Garnet) or YLF (Yttrium Lanthanum Fluoride).
- Doping is relatively high, i.e. about 50% of the Y ions in YAG are replaced by Er ions.
- In medical applications and especially in dentistry, the Er lasers represent highly developed commercial lasers with very high yield and efficiency in tissue removal.
- It is the type of laser currently used for dental hard tissue ablation **(Fig. 1.10)**.

Wavelength

Nd: YAG 1.064 μm
Ho: YAG 2.14 μm
Er, Cr: YSGG 2.79 μm
Er YAG 2.94 μm

Fig. 1.10: Example of Er:YSGG unit

Host Crystals

YAG (Yttrium Aluminum Garnet)
YSGG (Yttrium Scandium Gadolinium Garnet)

Pumping → Optical by flash lamps or laser diodes.
Operation mode → Cw, pulsed

CHAPTER 2

LASER SAFETY

- Introduction
- Classification of Light
- Laser Classes
- Secondary Hazards
- Protective Measures
- Organizational Protective Arrangements
- Evaluation

INTRODUCTION

The aim is to focus on the properties, effects and especially on the dangers of laser and LED radiation and to introduce several protective arrangements.

Lasers are excellent tools, but they also bear a high risk for severe injury and damage.

Reasons for Laser Safety Education

Laser radiation is like a sharp knife – excellent for cutting, but in case of an accident the injury can be very severe **(Fig. 2.1)**.

Laser radiation mainly endangers Eye and Skin.

Fig. 2.1: Laser warning sign

In the Eye—retina, cornea and the lens are especially of great concern. Damage to the retina cannot be repaired. Thus, just a slight carelessness can destroy vision for the rest of one's life. Skin is less sensitive and damages only at higher energies.

- Suitable protective arrangements dependent on laser power.
- Working with lasers requires good training.

The requirement to control and verify the correct implementation of the necessary protective arrangements necessitates an intensive safety education.

The impact of laser radiation on biological tissues depends not only on the radiation properties (e.g. Wavelength, intensity or irradiation time) but also on the irradiated tissues.

Its optical and thermal properties determine the absorption, reflection and transmission characteristics of the applied radiation. The spectral coefficient of absorption indicates the fraction of energy being absorbed when penetrating a layer of certain thickness. The optical properties of tissue determine the extent and the form of the coagulation zone.

Maximum Permissible Exposure

The maximum permissible exposure values (MPE – values) are limiting values that have been determined in experiments just as have other chemical or physical influence factors. MPE – values are defined separately for skin and eyes. Their physical units are W/M^2 and J/m^2. The specified MPE – values are always determined by national standards.

CLASSIFICATION OF LIGHT

Wavelengths and their Penetration Depth (Fig. 2.2)

UV-C : λ = 100 – 280 nm
Tissue absorption very high → nearly no penetration depth
Skin: Erythema
Eye: Photo conjuctivitis, Photo keratitis

UV-B : λ = 280 – 315 nm
Skin: Erythema
Eye: Photo conjunctivitis

UV-A : λ = 315 – 400 nm
Radiation penetrates several mm into skin
Skin: Sensitivity relatively low
Eye: Cataract

VIS : λ = 400 – 700 nm
Short wavelengths (Blue light): photochemical damages (particular skin, ocular lens, retina)
Long wavelengths (Red light): thermal damages (burning, coagulation)

IR-A : λ = 700 – 1400 nm
Particular eye: Radiation reaches retina, coagulation and burning.
Higher intensities: Cataract
It is very dangerous.

IR-B : λ = 1400 – 3000 nm
Penetration depth decreases strongly
Eye and skin: Only thermal effects (burning, coagulation).

IR-C : λ = 3 nm – 1 mm
Penetration depth < 1 mm
Only thermal effects on skin and eye.

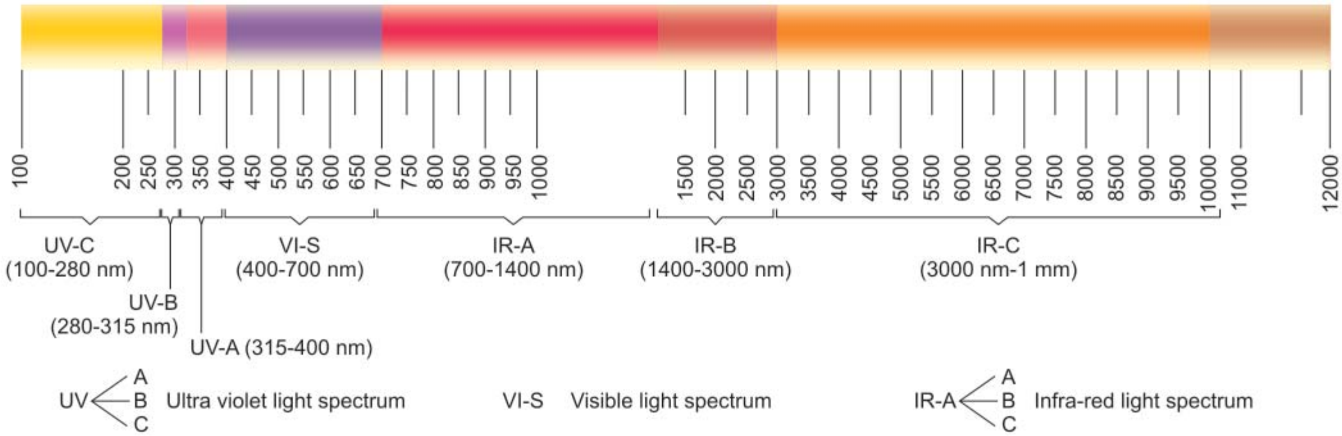


Fig. 2.2: Classification of different wavelengths of light

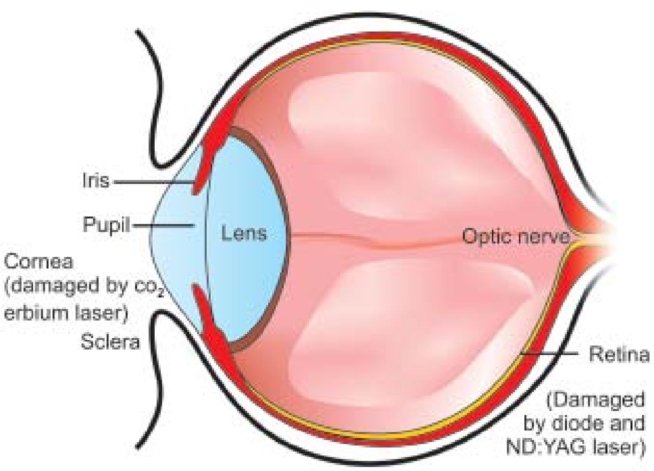


Fig. 2.3: Effects of different laser wavelengths on eye

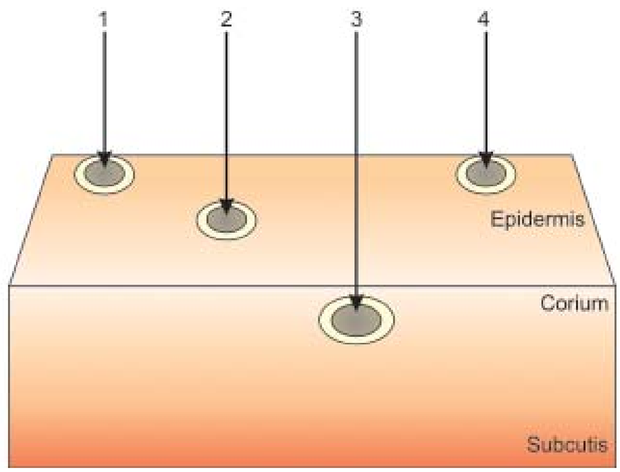


Fig. 2.4: Impact of laser beam on skin

Effect of Laser Beam on the Eye (Fig. 2.3)

When 7 mm aperture (Iris) focused on a spot of 10 µm in the fovea.

Iris shrinks about 700 times whereas the fovea shrinks 49 more times therefore intensity in the fovea is 49,000,000 times higher than on the cornea. Hence protective eye wear is imperative.

Impacts on Skin (Fig. 2.4)

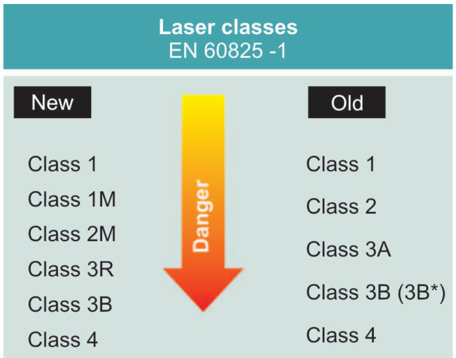
1. $\lambda < 280$ nm (UV-C)
   Light is absorbed in the uppermost layer of the epidermis.
2. $\lambda = 280$-400 nm (UV A+B):
   Light is absorbed in the epidermis.
3. $\lambda = 400$-1400 nm (VIS+IRA):
   Light is absorbed in the corium.
4. $\lambda > 1400$ nm (IR B+C):
   Light is absorbed in the uppermost layer of the epidermis.

LASER CLASSES

Laser devices have to be classified by the manufacturer according to their hazard to enable the user to choose the right protective arrangements.

The different laser classes are defined in the International safety standard IEC 60825 – 1 and in the European standards EN – 60825 -1 (Table 2.1).

Table 2.1



According to the European standard EN 60825-1
7 new and 6 old classes.
Danger rises with rising number of laser classes

The classification of the laser is always done by assuming the worst–case hazards:

- The user uses a magnifying glass or other optical device.
- Minimal distances during measurement.
- Longer exposure time than usual.
- Consideration of foreseeable failures.
- No consideration of the user's actual training.

Class 1

Safe laser devices are referred to Class I.

Very low output power device that remain under the MPE – values even at long irradiation times. Under high output power device – they are fitted with a protective housing that prevents the radiation from emerging to the outside under all normal operating conditions.

Condition: Below 40 μW in the blue
400 μW in the red spectral range
E.g.: CD players, range finders.

Protective arrangements: None.

Warning: None.

Class 1M

The new laser safety standards define a new class for laser devices being safe to the naked eye but bearing safety hazards for the use of optical instruments called class 1 M ('M' – magnifying instruments).

Warning: Laser Radiation. Do not view directly with optical instruments. Class 1M laser product.

Class 2

Only defined for visible wavelengths (λ = 400-700 nm)

Natural reaction of a person is to turn away (e.g. Shutting of the eyelid, time: appox 25s) are sufficient for eye protection. The output power of the laser devices is low enough to cause no damage within this time span. Laser devices of class 2 are safe as long as the reflex of turning away is not suppressed (e.g. Intentionally looking into the beam) or affected (e.g. by medicaments, drugs, etc).

Condition: For CW lasers, output power below 1 mW. (with an assured diameter of 7 mm for the Iris an average intensity of about 25 W/cm^2 is achieved on the camera A/c to corresponding MPE – value).
E.g.: Laser pointer, targeting lasers.

Protective arrangements: None.

Warning: Laser Radiation. Do not stare into beam.

Class 2M

The new laser safety standards define a new class for laser devices being safe for the naked Eye upto 0.25s exposure time but bearing safety hazards for the use of optical instruments called class 2M.

Warning: Laser radiation. Do not stare into beam or view directly with optical instruments class 2M laser product.

Remarks on Laser Classes 1M and 2M

- 'M' means "Magnifying Instruments".
- Lasers of these classes are safe for the naked eye.
- It can be dangerous if optical instruments such as magnifying glasses or telescopes are used.
- In these cases the MPE – values can exceed and can damage the eye with short irradiation times.
- As such instruments focus a larger light intensity into the eye; the rise of the exposure is evident.

Class 3A

Exposure is similar to class 2 in the visible range and class 1 in the invisible range without use of magnifying instruments. If optical instruments are used, damage can occur within 0.25s as a result of focusing. The reflex of turning away is no longer sufficient protection.

Condition: Output power below 5 mW and intensities below 25 W/cm^2 for the visible range.

5 times the limits of class 1 in the invisible range as long as the MPE – values are not exceeded.

E.g.: Lasers for measurements, lasers for building grounds.

Protective arrangements: Laser protective eye wear, attenuation filters, organizational protective arrangements, training to the users.

Warning: Cases class 3A (or 1M, 2M); Do not stare into the beam (3A, 1M), also when using optical instruments (3A, 2M).

In newer laser safety standards this class is replaced by new classes 1M and 2M.

Class 3B

In certain cases eyes and even skin are endangered. Damage can occur at very short irradiation times. The reaction of turning away is no longer sufficient protection, and even accidental irradiation is dangerous (inside the danger zone) for the direct or specular reflected beam. In most cases there is no risk for diffuse reflection or irradiation of the skin.

Condition: Output power <0.5 W (UVA-far IR)

The thresholds for UV-B or UV-C are much lower,

E.g.: Lasers for measurements, laser shows and alignment.

Protective arrangements: Safety precautions for the danger zone (boundary, laser protective eye-wear) training, laser safety officer.

Warning: Laser radiation. Avoid exposure to beam class 3B laser product **(Fig. 2.5)**.

Fig. 2.5: Laser radiation safety

New Class 3R

"R" means "Relaxed".

The new class 3R can be seen as the junction between practically safe class 2 and the dangerous class 3B with regard to eye hazards. Even when the limit is exceeded by upto 5 fold, a real hazard arises only at the irradiation time of several seconds. It is important that lasers of class 3R are only operated by persons who have been instructed about the residual risks. Other safety precautions are not necessary.

Conditions: 5 × output power of class 2 in the visible range is not exceeded

Maximum 5 × output power of class 1 in the invisible ranges.

E.g.: Targeting laser, laser for measurement, laser for building sites, etc.

Protective arrangements: Impart training to the user, laser safety officer for lasers in the invisible range.

Warning: λ = 400 – 1,400 nm

"Laser radiation. Avoid direct eye exposure. Class 3R laser product".

All other wavelengths: "laser radiation. Avoid exposure to beam. Class 3R laser product."

Class 4

For output powers > 0.5 W

Eye and skin are endangered even at diffuse reflection.

Fire hazards for flammable materials in the beam path.

Conditions: Output power > 0.5 W

E.g.: Lasers for material processing, laser in medical therapeutic use, lasers for tissue ablation.

Protective arrangements: Technical protective arrangements for the danger zone, laser safety officer, training of the users, consideration of fire hazards.

Warning: Laser radiation. Avoid eye or skin exposure to direct or scattered beam radiation class 4 laser product (**Table 2.2**).

SECONDARY HAZARDS

They are caused in causal connection with the operation of the laser, but mainly independent of radiation characteristics.

Table 2.2

Summary of laser classes

	Long-term Irradiation		Short-term Irradiation		Diffuse Reflection	Irradiation of Skin
	Opt. Instr.	Free Eye	Opt. Instr.	Free Eye		
Class 1	Safe	Safe	Safe	Safe	Safe	Safe
Class 1M	⚠	Safe	⚠	Safe	Safe	Safe
Class 2	⚠	⚠	Safe	Safe	Safe	Safe
Class 2M	⚠	⚠	⚠	Safe	Safe	Safe
Class 3R	⚠	⚠	Low risk	Low risk	Safe	Safe
Class 3M	⚠	⚠	⚠	⚠	Low risk	Low risk
Class 4	⚠	⚠	⚠	⚠	⚠	⚠

Common Hazards

Mechanical Hazards

Particularly caused by mechanically moved parts.

Special hazards can be caused by high pressure in tubes and low pressures in the laser cavity.

Tubing: Gas tubes are usually under pressure. It should be mechanically secured to avoid uncontrolled lashing in case of burst.

Laser resonators: In CO_2 laser, glass tubes used in the resonator are placed very low. If they are incorrectly mounted they can implode at operational pressures.

There is also danger of explosion during exchange service of flash lamps used in solid state lasers.

Electrical Hazards

- The CE-Sign signifies that the construction of the device is safe
- Subsequent alterations to the device can affect the electrical security
- If an external cooling – water circuit has to be installed, a close contact between water and power lines should be avoided.

Chemical Hazards

They are mostly caused by the materials used in laser construction. Toxic fluorine and chlorine used as laser medium in excimer lasers. The gas containers have to be stored under secure conditions. Most dyes of dye lasers are toxic or neurotoxic substances. Contact with skin and inhaling of released vapors must be avoided. The laser tubes of Ar^+ and Kr^+ lasers contain highly toxic beryllium. Therefore, the dye should be handled with care.

Fire Hazards

Flammable materials represent a fire hazard during operation of lasers with high output power, mainly because of flammable material in the beam delivery system, on the operation area and in the surrounding areas.

Beam delivery system:

Potential danger occurs when the beam axis has been changed by alignment work if the beam directly or indirectly hits cooling tubes or the housing of the optical path. Special consideration should be given to the combustibility of inspection windows, sealings and the paint on the housing. Directly or indirectly reflected laser radiation has the highest potential for danger. Fire can occur if the wrong combination of filters and exhausted particles are chosen.

Specific Hazards

Plasma

Laser light generation in gas lasers as well as laser welding produces plasma. Laser welding and conventional welding both produce a bright welding plasma emitting intense ultraviolet and short waved blue light. This emission is called secondary radiation. Prolonged exposure can cause retinal damage, inflammation of the cornea and even erythema.

CO_2 Lasers

Particular HF–stimulated CO_2 lasers create Ozone around the resonator, irritating eyes and airways.

Vapor and Dust

Emission of vapors and dusts during material processing is lower than with other thermal methods. The emission can be divided into:

- Irrespirable dusts and vapor – No hazards for the user.
- Respirable dusts and vapor (aerodynamic diameter $<10\ \mu m$) - High health risk for user.
- Gases.

Metals

During cutting of metals such as stainless steels, chromium and nickel are set free. Nickel and all its derivatives definitely are carcinogenic, whereas for chromium only Cr VI is dangerous.

Organic Matters

Particle diameters are between 0.07 mm and 0.25 mm, comparable to metals. The diameter tend to decrease with increasing generation of gaseous pyrolysis products.

PROTECTIVE MEASURES

The protective measure introduced follow the International standard IEC 60825-1 and the European standard EN 60825-1. The prescribed measures always describe the minimum safety requirements to be fulfilled.

Laser Protective Eyewear

The standard EN 207 (following up the DIN) requires a safety level for protective glasses whereby not only the laser radiation is attenuated to MPE–values, but the filter material withstands the specified laser power.

Only the filter's transmittance T[λ]has to reduce, visible the specified wavelength to the MPE-value without strong suppression of the other, only then normal work can be carried out with goggles worn. Laser goggles are not designed for prolonged looking into the direct beam, but only for accidental irradiation. The resistance of a filter against laser radiation is analyzed by examining if the optical density persists at least for 10s. Protective level of 5 means that the optical power density is at least 5 and the filter withstands the maximum power density this filter may be exposed to **(Fig. 2.6)**.

Fig. 2.6: Laser safety goggles

EN 207 requires that:

- The goggles must transmit at least 20% of the visible radiation, otherwise the manufacture has to inform about it in written form.
- The goggles must not lose their protective grade even at longer UV irradiation.
- The goggles have to keep their protective effect even at high temperatures (55°C) and high humidity.

Table 2.3

Operation modes for labelling laser protective eyewear		
	Operation modes (simplified)	**Pulse duration**
M	Mode-coupled lasers	$<10^{-9}$ s
R	Q-switched lasers	from 10^{-9} s to 10^{-7} s
I	Pulsed laser	from 10^{-7} s to 5 x 10^{-7} s
D	Continuous wavelasers	from 0.1s [if 315 nm - 100 nm, then > 0.5 ms]

- Wavelength and protective grade must be specified on the goggles.
- The instructions for use (in the language of the country it is distributed in) have to contain all the relevant specifications of the goggles.

Labeling

EN 207 demands the following scheme for labeling laser goggles:

DIR : Operation mode (WPMS)
1060 : Wavelength (λ) in mm
L6A : Protective level
RH : Sign of the manufacturer
DIN : Testing standard

a. **Operation modes (simplified):** The letters come from the German standard and have to be verified for the specific languages.

As a precaution, all goggle have to be tested for CW.

If no operation mode is shown at all the goggles can be used for CW.

All tested operation modes have to be declared.

D = CW (Dauerstrich)
I = Pulsed (Impuls)
R = Superpulse (Riesenpule)

b. **Wavelength:** Written in nm, also the indication of ranges is possible.

Warning: The wavelengths 1064 nm (Nd: YAG) and 10,600 nm (CO_2) can easily be confused.

Goggles only for CO_2 radiation do not protect against Nd:YAG radiation.

c. **Protective level:** According to wavelength and operation mode, different protective levels can be indicated.

E.g.: for different ranges of wavelengths
λ = 570 – 620 nm L5A RH DIN
λ = 620 – 900 nm L4A RH DIN
E.g.: for different operation modes
D 1060 nm L5A CZ DIN
IR 1060 nm L3A CZ DIN

The required protective grade for a certain laser unit has to be written in its handbook.

Many Goggles also are marked with the CE sign.

Letter L = filter withstands full radiation for more than 105 or 100 pulses.

Number N – 1/10N of the power is transmitted **(Table 2.4)**.

Table 2.4

Protective eyewear
(Classification of protective glasses for lasers)

DIR	1064	L6	RH	DIN
Operation mode	Wave-length	Protective grade	Manufacturer	Standard
O	W	P	M	S

Operation modes:
D = cw (Dauerstrich)
I = pulsed (impuls)
R = superpulse (Reisenpule)

Protective grade:
- Letter L = filter withstands full radiation for more than 10 s or 100 pulses
- number N = $1/10^N$ of the power is transmitted

Directions

Protection of the Eyes

If a free propagating laser beam is operated, protective eyewear should be worn as procedure.

When laser goggles are used it is important to check whether they are suitable for the operated wavelength.

The necessary protective grade, e.g. L3 or L5 can be calculated.

It should be ensured that the goggles transmit sufficient visible light apart from the laser wavelength.

Before each use, the goggles should be checked for faults.

Scratches, cracks or discolorations reduce safety.

Defective goggles must never be used.

Goggles with glass filters are heavy.

A new development is systems where reflection layers are sputtered on plastics, thus allowing high protective grades at low weight.

Windows

The laser safety officer has to consider the estimated irradiation time for windows and shieldings by means of a risk analysis.

It also has to be assured that the beam axis does not hit windows and doors.

Laser with shorter wavelengths can reach into the neighboring rooms.

For these wavelengths, windows and shieldings have to be covered with absorbing materials.

Reflecting Surfaces

They not only reflect laser radiation, but can even focus it.

The use of matt finished instruments and a suitable covering of reflecting surfaces in the mouth (metallic fillings, etc. is recommended in dentistry.

ORGANIZATIONAL PROTECTIVE ARRANGEMENTS

Nomination of a Laser Safety Officer (LSO)

The LSO on one hand has the duty of training the employees and on the other hand has to set the rules governing access to the laser zone.

If only laser devices of class 1, 1M, 2, 2M or 3R (visible) are operated, no LSO is necessary.

He is necessary when using lasers of class 3B and 4, 3R if invisible.

Duties and Responsibilities of Laser Safety Officer

- Performance of hazard analysis in the rooms where the lasers are operated.
- Advise to the responsible operator and for the supervisors of the laser areas for safety aspects.
- Choice of the personnel – protection equipment.
- Co-operation in laser safety education for employees working with laser devices.
- Co-operation in examination and official acceptance of laser devices according to national rules and regulations.
- Scheduled checks that the prescribed protective measures are being observed.
- Information of the responsible operator and the supervisors of the laser areas on defects and failures of laser devices.
- Investigations of all accidents and incidents involving lasers, and forwarding of all relevant information on preventive actions to all involved persons including the safety officer.

Additional tasks can be:

a. Decisions on technical and operational protective measures.
b. Advice of employees working with lasers or supervising them.
c. Preventing the use of lasers if necessary.
d. Contacting authorities and keeping in touch with them.

EVALUATION

The health and safety guidelines of the employee safety law demands an evaluation of all work places concerning possible danger.

An evaluation scheme could contain the following aspects:

- Definition of the evaluated area (department, location)
- Description of the work place in the laser control areas (activities)
- Description of the laser device (i.e. the tools and supplies for work)
- Laser class
- Wavelength
- Output power (according to accessories)

- Accessories
- Identification of the hazards and the risk
- Damage of the retina
- Nominal hazard zones (NHZ, usually information from the manufacturer)
- Fixing of the protective measures
- Documentation (health and safety protection documents).

The documents of the evaluation have to be updated regularly!

CHAPTER

3

LASERS IN PREVENTIVE DENTISTRY

- Introduction
- Conventional Treatment Methods
- Laser Application in Preventive Dentistry
- Mechanism of Laser Irradiation and Improved Caries Resistance
- Effect of CO_2 Lasers on Caries Prevention
- Effect of Argon Lasers
- Effect of Nd: YAG Lasers
- Effect of Er : YAG, Er, Cr:YSGG, Ho : YAG and UV Lasers

INTRODUCTION

The acidogenic bacteria produce acids as byproducts of their metabolism that can dissolve tooth mineral. They are also termed as cariogenic bacteria. The acids produced when they metabolize fermentable carbohydrates are predominantly lactic, acetic and propionic acids. Lactic acid dissociates more readily than the other acids. As the pH is lowered, acids diffuse into underlying enamel or dentin, dissolving the mineral. The two most important groups of bacteria that produce mostly lactic acid are *Streptococcus mutans* and *Lactobacilli*. The mineral crystals of the teeth and bones are made of carbonated hydroxyapatite. It is much more soluble than the hydroxyapatite which is in turn more soluble than fluorapatite.

Saliva plays a critical role in the prevention or reversal of the demineralization process, providing calcium in the plaque fluids, proteins and lipids that form a protective pellicle on the surface of the tooth, antibacterial substances and buffers.

The saliva components neutralizes the acids produced by bacterial metabolism in the plaque, raise the pH and reverse the diffusion gradient for calcium and phosphate thus returning calcium and phosphate into subsurface lesion where these ions regenerate new minerals on the surfaces of the crystal remnants that were produced by demineralization.

These remineralized crystals now have a veneer or less soluble mineral **(Figs 3.1A to C)**.

If fluoride is present in sufficient quantity, it enhances the remineralization process and is included in the new veneer on the subsurface crystals to form fluorapatite crystal, which has low solubility.

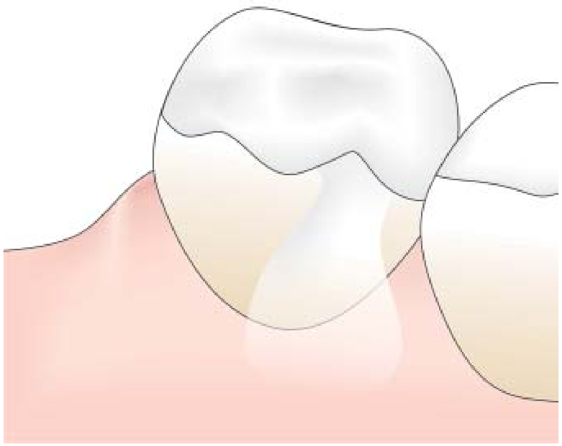


Fig. 3.1A: Preoperative diagrammatic representation

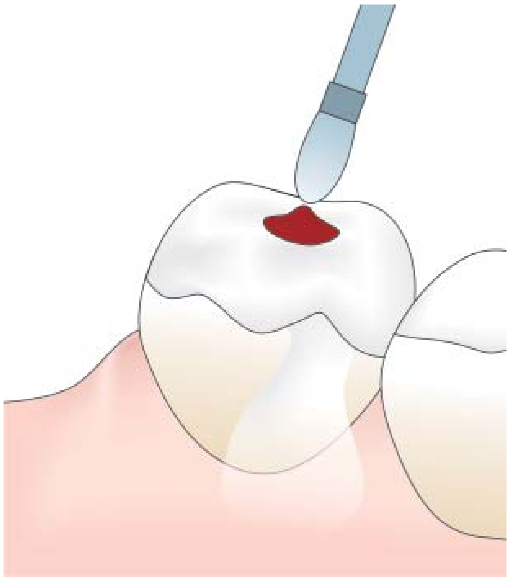


Fig. 3.1B: Application of fluoride gel on the tooth

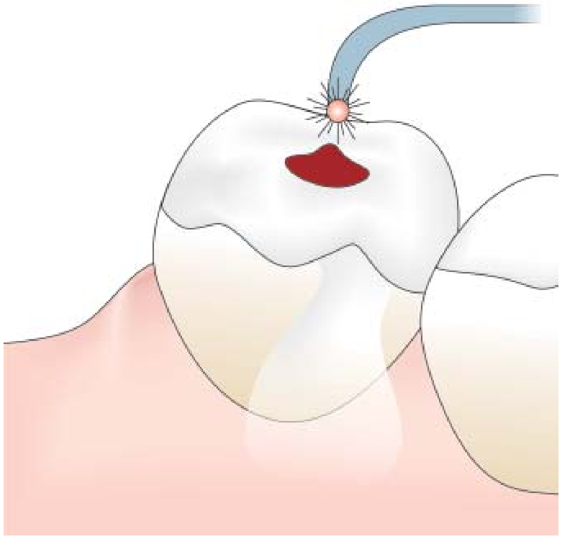


Fig. 3.1C: Activation of the fluoride gel by laser

CONVENTIONAL TREATMENT METHODS

The primary caries preventive agents are fluoride and fissure sealants in the conventional treatment system.

Benefits from fluoride are derived from both topical and systemic uses. Fluorides can be found in dentrifices, oral rinses and professionally applied methods, tablets and drops. The fluoride is less effective for pits and fissures than it is for smooth surfaces on teeth. Pit and fissure sealants have been developed to overcome this problem. Sealants are used to fill in anatomical pits and tissues that normally are too narrow for the removal of bacterial plaque by the bristles of a tooth brush. However complete or partial loss of sealant and secondary caries is common.

The optimum fluoride level that would inhibit caries development may vary from individual to individual and also most likely from site to site within the dentition (e.g. tissues, proximal surfaces).

LASER APPLICATION IN PREVENTIVE DENTISTRY

The mechanism of action of laser caries prevention is complex and involves both physical and chemical effects.

Laser activated fluoride forms an important part of the modern armamentarium for caries prevention. The value of laser treatment for caries prevention is now becoming widely recognized in the field of laser dentistry. Laser preventive therapy can be applied to prevent caries from developing, or to reduce the progression rate of existing lesions on the enamel and root surfaces of teeth.

Light Interaction with Dental Hard Tissues

The laser-tissue interaction must be understood thoroughly to ensure safe effective treatment for any procedures using lasers.

The laser-tissue interaction is controlled by the irradiation parameters: wavelength, continuous or pulsed emission, repetition rate, pulse duration, pulse energy, beam size and delivery method, spatial and temporal characteristics of laser beam, and optical properties of the tissue. The dentists can choose appropriate wavelengths and other laser conditions with provided parameters to perform the desired tasks.

The optical properties of special interest for caries detection, caries removal by ablation, or prevention of caries progression, are **transmission, scattering** and **absorption**. If light is transmitted mostly through the tissue with no interaction, it passes into underlying tissue. This is the case when absorption is minimal. If the light is scattered, it is no longer a coherent beam and is not delivered where it is needed.

When light is absorbed it interacts with the atoms in the tissue and generally is converted to heat. The degree of absorption determines the depth of penetration and the amount of heat deposited. The optical properties are characterized by the refractive index of the tissue, the scattering coefficient (λs), the absorption coefficient (λa) and the scattering anisotropy. The ultimate effects of laser irradiation on the tooth tissue depend on the distribution of the energy and how much is deposited in the tooth.

The temperature rise at any point is a balance between the energy deposited in a specific time and energy that is conducted away as heat. The temperature rise determines whether the morphology or chemical characteristics of the tissue at that point are changed.

Scattering and Absorption Parameters

Absorption and scattering coefficients are determined experimentally and are given values with units of reciprocal centimeters (cm^{-1}).

For materials with high absorption coefficients (>100 cm^{-1}), the laser energy is absorbed within about 100 μm of the surface and converted to heat. In case of pulsed laser, if the pulse duration is short enough, nearly all the energy is deposited as heat in this region however if it is longer, some heat is deposited in the upper layers and the remaining energy is transmitted deeper into the tissue. Once the irradiation energy is transformed into heat, its further penetration into the tissue is done via heat conduction Energy transfer into the tissue is by conduction of heat. This transfer is determined by the thermal diffusivity and heat capacity of the tissue. Wavelengths with high absorption correspond with specific components in the tissue.

For example, the extremely high absorption co-efficient for dental enamel at λ = 9.6 μm, wavelength produced by a CO_2 laser, is due to the phosphate ions in the carbonated apatite material.

Weak Absorption in Visible and Near-Infrared

Enamel absorbs visible light weakly in the λ = 400-700 nm region (absorption coefficient <1 cm^{-1})

- moderately in the UV λ = 240-300 nm region (absorption coefficient about 10 cm^{-1}).

The scattering coefficient decrease rapidly between λ = 240 nm and 700 nm and are even lower in the near infrared, with values falling from 400 to 15 cm^{-1} over that range.

In the region of Nd: YAG laser at λ = 1.064 nm, the absorption coefficient in enamel is low (<1 cm^{-1}), implying that light in the visible and near-infrared readily passes through enamel almost entirely, with minimal absorption and less scattering as the wavelength is increased.

Dentin has a much higher content of water and protein than enamel. Like enamel, dentin absorption is low in the visible region (λ = 400-700 nm), but the tissue scatters much more than enamel. The tissue has low but measurable absorption at Nd: YAG wavelength and scatters highly compared with enamel at this wavelength. Scattered Nd: YAG light continues to move through the tissue until it is all absorbed or transmitted to a surrounding tissue.

Strong Absorption at Specific Wavelengths in the Mid-infrared

The mineral content of enamel and dentin is a carbonated hydroxyapatite. Also enamel and dentin contain a substantial amount of water among the crystals. The transmission spectrum of enamel clearly illustrates the absorption bands for water at approximately 3 µm, hydroxyl at approximately 2-8 µm, carbonate at approxly 7 µm and phosphate at 9-11 µm.

The absorbtion co-efficients at these wavelengths that coincide with the constituents of the tissues are high (800 to 8,000 cm^{-1}). For absorption values as high as this, transmission is low.

The Er: YAG laser (λ = 2-94 µm) overlaps the absolute maximum of the water absorption band, as the principal absorber is water in both enamel and dentin. The Er: YSGG (λ = 2-79 µm) also overlaps the hydroxyl ion absorption in the mineral, heating the mineral as well as the water, contributing in two ways to the heating of the subsurface tissue and effective ablation.

The conventional CO_2 lasers used in medicine and dentistry emit light at λ = 10.6 µm, which is absorbed mostly by mineral.

There are four principal wavelengths of CO_2 laser, each of which can be produced by appropriate changes in laser configuration. These are λ = 9.3, 9.6, 10.3 and 10.6 µm.

Light at wavelengths of λ = 9.3 and 9.6 µm is strongly absorbed by the mineral. This implies, that if there is an application that requires efficient and short heating of the mineral 9.3 and 9.6 µm would be the preferred wavelengths.

MECHANISM OF LASER IRRADIATION AND IMPROVED CARIES RESISTANCE

Changes in Enamel Composition

Theories regarding the mechanism by which laser irradiation enhances enamel resistance to artificial caries, range from a physical seal achieved by meeting the surface through partial fusion and recrystallization of enamel prisms, to changes in enamel composition only. The enamel surface is sealed by the laser and is less permeable to the subsequent diffusion of ions into and from the enamel.

Thermal treatment converts carbonated hydroxyapatite mineral to a less soluble mineral and the dissolution rate decreases after a 24-hr heat treatment at 350°C. This change in solubility after low temperature treatment can be attributed to the thermal decomposition of more soluble carbonated hydroxyapatite into less soluble hydroxyapatite. The optimum temperature change for clinically applicable caries preventive treatment has not been determined due to the complexity of the thermal decomposition of these materials.

The alteration in the composition of mineral phase with the decrease of carbonate, water and organic content, results in reduction of lattice strain of hydroxyapatite and decreased solubility.

Studies shown that there was a reduction in the carbonate, water and apatite hydroxide content when a continuous wave CO_2 laser was used.

The lower the carbonate content, the lower the dissolution rate. The CO_2 laser produced a temperature rise (>1000°C) at the surface which was sufficient to fuse and meet enamel crystals composed of carbonated apatite.

This surface melt zone was no deeper than 5 µm, beneath which there was a region of interaction 10–40 µm deep, where the temperature rise was insufficient for the sintering process but sufficient for some compositional changes to the crystals.

Creation of Microsive or Micropore System

The creation of microsive or micropore system within the mineral structure following the laser treatment provides a means for trapping calcium, phosphate and fluoride ions released during demineralization. These micropores then act as sites for re-precipitation.

During the demineralization process, dissolution of mineral occurs with mobilization of ions from the affected dental hard tissue. As mineral phases are released from the deeper layers of the hard tissue, re-precipitation in the more superficial or adjacent layers occurs and the surface remains intact. Such a network has been described for lased enamel by quantitative polarized light techniques. The trapped mineral phases inside it impede lesion formation and progression and cause enhanced resistance against demineralization. There is an enhanced uptake of fluoride, calcium and phosphate from endogenous and exogenous sources in lased dental hard tissue, due to the altered pure structure of enamel cementum and dentin.

In particular, the affinity for fluoride may result in redistribution of fluoride to root and enamel surfaces during demineralization, facilitating re-precipitation of the mineral phases into the tooth surface.

The surface enamel is known to contain an increased amount of fluoride compared to the underlying enamel. The creation of globular deposits with or without formation of a confluent surface coating may provide a reservoir for mineral phases during a cariogenic attack. The demineralization may be lessened and remineralization of the enamel surfaces by mineral phases acquired from the surface coatings, oral fluids and other exogenous sources may be facilitated.

The globular deposits may provide readily mobilized tooth mineral which may get redeposited into the underlying root surface during a cariogenic challenge and this in turn, can enhance resistance to caries formation.

The loss of water, carbonate and organic substances from enamel would have caused the formation of microspaces, which was suggested by the change of the optic character. There is high fluoride uptake in lased enamel as the permeability is higher than that of unlased enamel and this could be attributed to the existence of microspaces.

The size of microspaces seems to be smaller than the micropore in caries lesions. Reduction of carbonate content reduces the acid solubility of enamel.

The carbonate reduction and the decrease of lattice strain contributes to acid resistance.

Mechanism

Change in enamel composition

- Chemical and morphological changes in enamel
- Physical seal by melting the surface through partial fusion and recrystallization of enamel prisms, to changes in enamel composition.

Creation of a microsive or micropore system

- Means for trapping calcium, phosphate and fluoride ions released during demineralization
- Acts as a site for reprecipitation.

EFFECT OF CO_2 LASERS ON CARIES PREVENTION

Dental hard tissues strongly absorb light in certain regions of infrared spectrum, because of phosphate, carbonate and hydroxyl groups in the crystal structure. The CO_2 laser produces radiation in the infrared regions that coincides closely with some of the apatite absorption bands. This kind of laser can operate at discrete wavelengths between $\lambda = 9$ µm and $\lambda = 11$ µm. There are four principal vibrational emission bands which are centered at $\lambda = 9.3$ µm, $\lambda = 9.6$ µm, $\lambda = 10.3$ µm and $\lambda = 10.6$ µm, each consisting of several discrete rotational lines. The molecular groups mainly corresponding to the emitted CO_2 laser wavelengths in enamel are the phosphate groups with a strong absorption band near 1,000 cm^{-1} (= 10 µm).

Commercially available CO_2 lasers are based on the wavelength of 10.6 µm and can be adapted to operate at the other wavelengths by various dispersive and nondispersive methods. In contrast, to most other laser wavelengths, scattering is negligible in dental enamel at mid–IR wavelengths ($\lambda = 3$-12 µm).

The energy deposition is determined by

a. Absorption coefficient
b. The tissue reflectance

It is preferable to use as little energy as possible because the cumulative energy determines the rise in pulp temperature. The laser treatment parameters include wavelength, pulse duration, pulse number, repetition rate, pulse energy and spot size. Small changes in laser treatment parameters can sometimes result in a significant change in the caries inhibition achieved.

Surface Characteristics

In SEM observation, the unlased enamel or dentin surfaces showed the presence of a smear layer that occluded the enamel rods and dentinal tubules.

The lased enamel and dentinal surfaces were partially melted and solidified, thus the enamel rods and dentinal tubules were not visible due to complete removal of the smear layer after demineralization with 0.1 M lactic acid. The lased surfaces were almost unchanged even after demineralization and lased areas were found to be melting with solidification of smear layer. This suggests that a CO_2 laser could sufficiently melt and solidify the smear layer and thus enhance resistance to artificial caries like formation.

Moderate heat treatment by a CO_2 laser reduced the solubility of dental enamel and carbonated apatite. Pulsed CO_2 laser produced a temperature rise >1,000°C at the subsurface, sufficient to fuse and melt the crystals. As a result of the SEM examination, the lased dentin appeared to be sealed at all four energy densities used, but a smooth surface was only obtained when the energy density did not exceed 425 J/cm^2.

The sealed dentin contained no tubular structure, whereas in the underlying dentin the dentinal tubules retained their normal aspect. The lased dentin is less permeable to acid.

There are two interpretations possible:

1. Acid penetration occurs through unsealed dentin areas.
2. The micro-cracking provides diffusion pathways to the underlying sound dentin.

The sealed layer of dentin seemed to be acid resistant because the mineral content of the sealed layer was increased. There is increased calcium and phosphate found in lased and recrystallized dentin, this increased mineral content is due to the burning of the organic matter from the tissue (In melted dentin, water is evaporated, organic material is combusted, hydroxyapatite is fused).

Combined with Fluoride Treatment

The demineralization of enamel was reduced in the presence of 0.2 ppm fluoride for both laser and unlased enamel, there was only modest lesion development observed for unlased enamel. Laser irradiation of dental enamel results in significant reduction of the effective solubility of enamel mineral. There is a significant synergism between laser irradiation and fluoride solution. CO_2 laser irradiation with sodium fluoride (NaF) showed lowest mean Ca^{2+} ppm at the enamel or dentin.

SEM observation showed that surfaces were changed to melted, smooth and mirror-like appearances. So it can be concluded that CO_2 laser irradiation with NaF solution has a greater caries preventive effect than CO_2 laser irradiation only, at the enamel and dentin surfaces.

Clinical Application

- Lasers can be used to effectively modify the chemical composition of remaining mineral phase of enamel because the mineral, hydroxyapatite found in teeth contains carbonic inclusions that makes it highly susceptible to organic acids generated from bacteria in dental plaque.
- CO_2 laser operating at $\lambda = 9.3 – 10.6$ µm wavelengths can be effectively used to inhibit enamel demineralization.
- As a side effect of laser ablation, the walls around the periphery of cavity preparation will be transformed through laser heating into a more acid-resistant phase and have an enhanced resistance to future decay.
- Laser can be tightly focused to drill holes for micropreparations with very high aspect ratio (depth/diameter) well beyond the capability of the dental drill, which is limited by the size of the dental bur. This is of particular importance since the early caries lesions are typically localized to the pit and fissures on the occlusal surfaces of the posterior dentition.
- Laser have the potential to substantially reduce the amount of tissue that needs to be removed for cavity preparation.

EFFECT OF ARGON LASERS

The Argon laser emitting at λ = 488 nm and λ = 514 nm has been effective in reducing loss of tooth structure and size of subsurface lesions on both root and enamel surfaces at relatively low fluence levels (12 J/cm^2).

Argon laser may be particularly useful for reducing the caries susceptibility of sound enamel in high caries risk patients, and may also have the value for treating white spot lesions. The combination of low fluence argon laser radiation (10-12 J/ cm^2, 10 seconds) with fluoride preparations results in even greater reduction in lesion depth than when either modality is used alone. The combination greatly decreases mineral loss after a strong acid interaction, relative to unlased enamel. Lesion depth reductions with argon laser combined with 1.23% acidulated phosphate fluoride (APF) have been reported as 25%, 75% and 51-55%. Argon laser with 2% neutral sodium fluoride (NaF) reduced the lesion progression by 29%.

Mechanism of Action

On Enamel

The effect of laser irradiation on dental enamel reported changes in the crystal structure of hydroxyapatite, together with a reduction in the extent of dissolution following acid challenge. A decrease in the permeability or solubility of enamel (or a combination of both) is common explanation for the effect of laser radiation on enamel. Irradiation with high intensity infrared laser radiation ultimately leads to formation of pyrophosphate, which is responsible for decreased enamel solubility in acidic conditions. The laser irradiation of enamel reduces the critical pH at which enamel dissolution occurs, from 5.5 to 4.8. The critical pH is further reduced in the presence of fluoride, even at concentrations as low as 0.01 ppm to 4.3. The CW argon laser irradiation of tooth enamel (67 3/cm^2) leads to reduction in water, carbonate and organic substances, resulting in the creation of microspaces. The presence of these microspaces accounts for the observed increased uptake of fluoride in lased enamel. The ions released from the enamel matrix, during demineralization gets trapped into the microspaces.

Mechanism for Laser Activated fluoride treatment include:

1. The creation of surface coating, on lased tooth structure which increases the affinity for fluoride, calcium and phosphate ions from endogeneous and exogeneous sources.
2. Swelling and denaturation of proteins on the enamel surface, with subsequent sealing of the surface pores.
3. Alternations of microorganisms in plaque that may be irradiated.
4. Stabilization and decreased solubility of hydroxyapatite.

On Root Surfaces

Unlike enamel, the root surface of a tooth is more susceptible to acid dissolution and caries due to its lower solubility product and higher critical pH.

Both cementum and dentin have a much lower mineral content and greater organic matrix content than enamel. Root surfaces exhibit a much greater ability for fluoride uptake than enamel. Although laser irradiation of the root surface is shown to be very effective at reducing carries susceptibility, the combination of fluoride with argon laser is even more potent. The combination resulted in a synergistic effect, gaining a greater reduction in lesion depth than either laser or fluoride alone. Laser radiation may create a micro sieve network in the root surface that may trap some of the more soluble mineral phases, effectively limiting the formation of a carious lesion.

Combined with Fluoride Treatment

Fluoride agents utilized either before or after the laser irradiation result in a significant reduction of lesion depth. Fluoride treatment provides 12,300 ppm fluoride and results in both labile and bound fluoride for retention within enamel.

Fluoride agents produce surface coatings that may act as diffusion barriers, reduce enamel solubility in acid conditions, act as a reservoir for fluoride-rich reaction products such as calcium fluoride and absorb protein and microorganisms from the enamel surface.

The combination of fluoride and laser irradiation has a synergistic effect on carries formation.

In the presence of fluoride, the threshold for sound enamel dissolution was reduced from pH 5.5 to 5.14. In lased enamel, it was reduced from pH 4.78 to 4.31.

Even low fluence laser treatment in combination with fluoride treatment provides a significant degree of protection against caries development and progression. It enhances the resistance of sound enamel to a cariogenic challenge. The future may provide dental visits that includes examination, prophylaxis, radiographs, sealants and topical fluoride treatment in conjuction with laser irradiation.

Clinical Application

- A significant caries preventive effect has been demonstrated when combining argon laser irradiation at low fluence level (12 J/cm^2) with APF treatment prior to lesion formation.
- Because it is possible to collimate the beam to a specific diameter and focus the beam to a selected depth, it may be possible to irradiate interproximal areas, especially beneath the contact area, which may be particularly susceptible to caries development.
- Also there is potential exists for improving caries resistance in enamel forming pits and fissures. This may occur while using an argon laser for polymerizing a visible light cured sealant material **(Fig. 3.2)**.

Fig. 3.2: Strawberry flavored fluoride gel

EFFECT OF ND: YAG LASERS

The effect of laser irradiation on tissues depends upon the interaction of the different wavelength photons with the target material and is the basis for the Nd: YAG and CO_2 laser, on a photothermal mechanism. The extent of the changes that occur within enamel and dentin is effected by the absorption characteristics of the substrate and the wavelength at which the laser operates.

Nd: YAG radiation at a wavelength of λ = 1.06 µm is affected to a much greater extent by the color and structure of the substrate and is not readily absorbed.

One of the limitations of the application of Nd: YAG radiation to the dental hard tissue is the variability in the color and composition of both enamel and in particular dentin. This can lead to considerable variations in the effect of this type of radiation when applied to different teeth. In order to produce a favorable result using Nd: YAG radiation, an energy absorbing initiator must be applied to the target surface to absorb the laser light. The absorbtion of the beam by the initiator results in the conversion of energy delivered to heat which in turn produces changes on the enamel surface. The efficacy of the initiator in conversion of laser energy to heat is demonstrated by the intensity of the changes observed in the target tissue.

Dentin, a more opaque material, shows variable absorption characteristics depending on its color and translucency. Translucent sclerotic dentin will absorb little or no Nd: YAG radiation; instead it is transmitted to the underlying structure—usually dental pulp.

Normal pulsed Nd: YAG laser is the most suitable for clinical use because of the high resistance against acid decalcification and the lesser amount of damage caused to the enamel surface. Nd: YAG laser can be guided to the target tissue through a flexible optical fiber.

It has been shown that fluoride application after laser irradiation produces a greater fluoride uptake in the smooth enamel surface than fluoride application before laser irradiation.

Nd: YAG laser has the potential to remove organic and inorganic debris from the pits and fissures without causing either enamel or pulpal injury. Cleaning with Nd: YAG laser irradiation was more effective in removing the pit and fissure contents than mechanical and chemico – mechanical methods. Normal pulsed Nd:

YAG laser irradiation is effective for increasing the acid resistance of the enamel of pits and fissures, as well as helping to remove the pits and fissures contents and increasing the fluoride uptake into the deep pit and fissure enamel.

Combined with Fluoride Treatment

Combined laser and fluoride treatment has been successful in increasing the resistance of the teeth against carious attack.

Studies shown that the combined Nd: YAG laser and fluoride treatment obtained the highest acid resistance compared to other treatments. During the microscopic evaluation of carious lesions, it seemed that the laser corrected the anatomic defects of pits and fissures by cleansing and odontoplasty like effects. Another possible mechanism of caries inhibition effect is achieved by melting and resolidification of the enamel surface crystal at the pit and fissure area.

During Nd: YAG laser irradiation, many partially coalescent globular granules are produced by the process of melting and the subsequent resolidification of enamel crystals. In this condition, fluoride can easily penetrate into the spaces between the granules. The microspaces formed by laser irradiation may trap the demineralized ions and provide space to allow them to combine with fluoride. The availability of fluoride ions from CaF_2 like material in the liquid phase around the apatite crystallites is more important in decreasing dissolution of crystallites than in incorporating fluoride into the crystal lattice.

Fluoride from enamel, treated with combined laser and fluoride varnish, undergoes prolonged release, resulting in greater deposition of CaF_2-like material, which facilitates remineralization of the lesion.

Clinical Application

Enamel treated with APF after laser irradiation became remarkably acid resistant. One explanation is that - it might be caused by the morphological microscopic alterations which follows the uptake of fluoride into the enamel. Another aspect is that high intensity infrared light from the pulsed Nd: YAG dental laser is absorbed by carious enamel and not by healthy enamel. The more conservative laser treatment removed the caries but not the sound enamel below the lesion. The pulsed Nd: YAG dental laser was found to be both safe and effective for surface carries removal.

EFFECT OF ER: YAG, ER, CR: YSGG, HO: YAG AND UV LASERS

Studies have shown that an **Er: YAG laser** used instead of acid etching, influenced artificial secondary caries formation in enamel and root surfaces. Er: YAG laser irradiation resulted in a 56% reduction in primary enamel surface lesion. Er: YAG laser with and without water mist appeared to be more effective for laser irradiation. SEM observation showed that the lased areas had melted and seemed to be thermally degenerated. Er: YAG laser influenced the deposition of CaF_2 on the enamel after the application of APF and shared a superficial anticariogenic action, but not in depth.

Ho: YAG laser (λ = 2, 120 nm) energy irradiation after application of resin/NaF to restorative margins and adjacent area have shown a significant increase in resistance to acid/mechanical destruction on cementum dentin root surfaces. The integrity of the restorative/dentin margins was maintained. SEM examinations of dentinal root surfaces showed consistently smooth surfaces with tubule closures when using topical resin with fluoride and Ho: YAG laser treatment.

Short UV laser pulses are primarily absorbed by protein and lipid localized between the enamel prisms, resulting in removal of intact mineral effectively etching the surface without thermal modification of mineral phase. Such modification is likely to increase the permeability of enamel surface and subsequent absorption of fluoride. The laser treatment followed by topical application of fluoride significantly increased the resistance to acid dissolution to a level of over 50%.

CONCLUSION

Laser available for utilization in dentistry include CO_2, Er:YAG, Er, Cr: YSGG, Ho: YAG, Nd: YAG and argon lasers, and in the near future also KTP and UV lasers.

The Argon lasers may occupy a prominent role in both caries prevention and restoration in the near future. It can affect the susceptibility of dental surfaces to caries initiation and caries progression, may reduce secondary caries and provide additional protection for the adjacent root surface. There is also the possibility of laser polymerization of light cured surface restorations. A flexible fiberoptic delivery system is easily adapted for intraoral use. Argon lasers operate at relatively low energy levels that are well tolerated by hard and soft tissues as well as the pulp.

On the other hand it is possible to utilize CO_2 laser irradiation at wavelengths of $\lambda = 9.3\ \mu m$ and $\lambda = 9.6\ \mu m$ to alter dental enamel to make it more resistant to subsequent acid attack. The advantages of CO_2 lasers are that, they not only inhibit caries, but can also be used to remove caries and thereby inhibit the decalcification of cavity wall.

The exposure of dental hard tissues to Nd: YAG laser irradiation also showed remarkable acid resistance as well as increased fluoride uptake of the irradiated tissues. The limitation of the application is he need for an energy-absorbing initiator to absorb laser light on the enamel surface.

4

CHAPTER

Lasers in Operative Dentistry

INTRODUCTION

Development of the Laser-assisted Cavity Preparation

In 1964, Stern and Sognnaes first experimented on hard tissue ablation with a ruby laser. Since that time, it has become the most explored field in laser dentistry. The first trials by Stern and Sognnaes with the ruby laser were not very successful, as this treatment led to a marked rise in temperature in the surrounding tissue and recognizable damage was observed. Similar results were later confirmed with Nd: YAG and the CO_2 – laser. In all these systems, massive thermal side effects led to dangerous temperature rises in the pulp as well as micro-cracks and carbonization. Reason for negative results is the direct thermal side effect of the explored wavelength on the dental hard tissue which leads to high temperature within the tooth. With the ruby and Nd: YAG laser, deep penetration of the radiation also leads to transport of heat to the pulp.

Wavelengths suitable for clinical preparation of dental hard tissue were formed with the excimer laser within the ultraviolet range. Since excimer laser showed only a restricted ability in clinical use, mainly because of ablation and technical reasons, the erbium based laser systems (Er: YAG and Er, Cr: YSGG) have become standardized treatment tools for dental hard tissues. Totally new ablation techniques were established in the 1990s. Through the use of ultra short pulsed laser systems of other wavelengths, with pulse duration of pico-or femto seconds, the thermal and mechanical stress was reduced. Further advantages are the possibility of precise preparation with a high selectivity for caries.

The primary indication for dental hard tissue treatment is the removal of tissue parts changed due to caries. Conventionally, mechanical methods are used which allow a more or less selective removal because of density differences between the regular and changed material. A few decades ago the "Extension for prevention" theory postulated by GV Black was mainly used in dentistry. Today, the selective removal of carious lesions combined with the very small loss of unaffected tissue is often requested. With the development of a variety of adhesive filling materials, the first step towards this was taken. Through the direct adhesion of the composites with the dental hard tissue, it is even possible to work with very irregular cavities and undercuts. The second main condition for allowing a maximum conservative preparation is a suitable tool, which enables the selective removal of the affected tissue.

CONVENTIONAL METHODS

Rotary Instruments

The development of dental turbines and angle pieces has proceeded rapidly in the last few decades. The high speed, the multi-edged tools and fine diamond grinding pieces have led away from the classical drilling procedure, to a more or less grinding form of tissue removal. A more precise and minimally invasive cavity preparation is facilitated. The smaller vibrating effect of these fine cutting tools, combined with efficient cooling techniques, e.g. threefold water spray leads to reduction of pain. Variety of rotating tools and angle pieces also allows the dentist fine adjustment of the tool. Another advantage is the possibility of shaping a very precise cavity form. This can be achieved by the geometrically exact form of the cutting tools as well as the tactile feed back during the preparation. One of the limitations is that caries selectivity and minimally invasive excavation is not possible with such instruments. Also during treatment a 1-5 μm thick smear layer is formed and has to be removed before new adhesive techniques can be applied. The other main problem is the heat developed during the cutting process. Temperature is mainly related to the cutting speed, the applied pressure and the sharpness of the drill. An effective cooling procedure is of major importance. The critical temperature rise lies at about 5.5°C, at which a high percentage of the pulp cells are killed. With every mm^3 of dentin removed, about 40,000 odontoblasts can be destroyed. In the case of excessive temperature rises, a pulpitis or necrosis can result. The reason for this can be too high a contact pressure or insufficient cooling. In deep cavities the dangers of bacterial infection of the pulp through invisible micro cracks is also present. A high rise in surface temperature leads to a significant weakening of the surrounding enamel. The use of water or aerosol sprays has to be looked critically because of the possibility of infection **(Fig. 4.1)**.

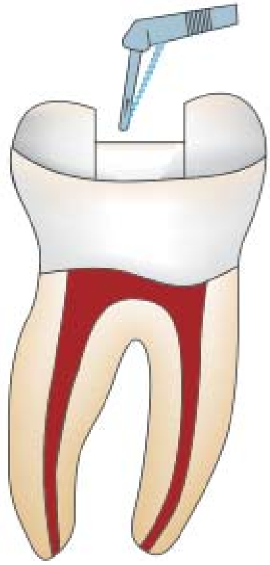


Fig. 4.1: Conventional cavity preparation using airotor showing well-defined cavity walls

Kinetic Cavity Preparation—KCP

Kinetic cavity preparation uses a high speed particle stream instead of rotating drilling and grinding tool for removal of material. Similar to sand blasting, aluminium oxide particles are used. From a reservoir, the particles are swept along in an air stream that leads through a tube to the hand piece where it is directed onto the preparation area. Through the collision of the particles with the surface, small fragments are torn out and an ablation process results. The pressure of these systems lies between 5 and 15 bar. The diameter of the spherical particles is 10-15 μm. This preparation technique allows a very fine ablation and therefore the forming of a lesion-specific cavity form. Through the difference in density of healthy and carious material, the selectivity of this method is comparable to the rotating instruments. Further advantage is the micro-retentive pattern on the cavity walls that enhances the bonding of the adhesive materials and the tissue. Smear layer does not occur and the use of acid etching techniques is not necessary. **Disadvantage** – Development of massive particle dust clouds. Therefore special arrangements have to be made to avoid the inhalation of the dust by the patient, the doctor and the assistant.

Cavity Preparation Using Lasers

In laser preparation, intensive electromagnetic energy (light energy) is used for ablation of the tissue.

Depending on the wavelength of the laser light, the ablative effect can be based on chemical or thermal effects (photo chemical or photo thermal ablation). The differential absorption of laser light by materials with different consistencies results in higher or lower ablation rates. This explains the selectivity of laser ablation. Erbium based systems became widely accepted for preparation of dental hard tissues. Through their specific ablation mechanism, they cause a micro retentive pattern in the walls of the prepared cavity. This enhances the adhesion between the composite material and the cavity. It also allows the use of adhesive materials without etching techniques and excludes the possible side effects like over etching, danger of injury, toxicity of the pulp as well as pain resulting from acid remaining in the dentin tubules. Erbium laser can also be used to prepare a fissure sealing. The use of the correct parameters is especially important. The pulse energy should be as small as possible to prevent changes to the structure of the tissue. One of the problems of laser preparation tools is that metallic fillings made of amalgam and noble metals cannot be removed **(Fig. 4.2)**.

The fillings reflect the light strongly, thus preventing efficient interference with the material. Toxic vapor can develop (e.g. mercury from amalgam). Phosphates, carboxylate, GICs, polyketones and composites can be easily removed with this method. Difficulties can also

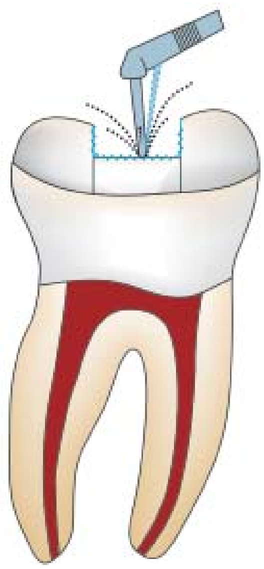


Fig. 4.2: Cavity preparation using Erbium laser showing irregular margins. Modern composites require conservative cavity preparation that can be easily achieved with the laser

occur during preparation of crown stumps or box preparation for inlays. The cavities have to be reworked with an ultrasonic device with a precision attachment. This is because of the uneven form of the cavity which has to be reformed for the inlay and to achieve the necessary gap width. Preparation techniques like parallelization, the formation of plane boxes and the correct preparation margins are limited by the production of rough margins and irregular cavity walls.

The laser offers the advantage of producing a retentive pattern for strong adhesion by composite cementation in the case of preparation for Maryland bridges, ceramic inlays or similar works with adhesive materials. The ablation speed of the laser is much slower compared to the rotating instruments. The ablation rate of the laser can be improved up to a certain level by accelerating the pulse energy.

Any increase above the optimized parameters leads to a decrease in both the thermal safety of the pulp and the structural integrity of the residual tissue. With an increase of the pulse energy, the generation of excessive microcracks in the dental hard tissues is possible.

To be able to use the advantages of the laser and protect the tooth from damage, the option of a longer preparation time with optimized parameters must be taken. Another typical property of the erbium laser radiation is the bactericidal effect, even though it has the lowest thermal side effect within the hard tissue.

The laser supported hard tissue preparation is similar to the conventional methods with the danger of inducing iatrogenic pulp damage through hyperthermia. The radiation tolerated by the pulp is mainly related to the conduction of the heat by the hard tissue. Therefore, it is highly influenced by the pulse duration and the form and shape of the applied pulses.

In comparison to the rotating instruments, the laser has one major advantage. Laser treatment is contact free, thus allowing direct cooling of the area with a water spray. With the absence of pressure and temperature pain, anesthesia can often be omitted. This is especially useful when treating traumatized people and children, as a calmer treatment procedure can be followed. Absence of the drilling sound, is also another advantage.

LASER SUPPORTED CAVITY PREPARATION

Er: YAG and Er, Cr: YSGG Lasers

The erbium-based systems are used for the treatment of dental hard tissues for various technical, physical and medical reasons. The advantage of the erbium wavelength is that it is better absorbed by water than by the dental tissues. Since the enamel and the dentin consist of a relatively high percentage of water, the laser has a very low penetration depth.

The strong absorption property of water is used to hold down the development of heat during ablation: since water absorbs the laser radiation better than the dental hard tissue, the temperature rise of the tissue is relatively low during ablation **(Fig. 4.3)**.

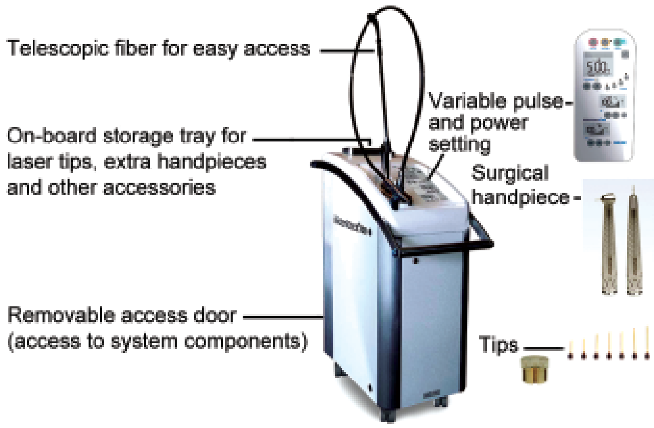


Fig. 4.3: Parts of Er:YSGG laser unit

Water reaches its boiling point and causes a micro-explosion in the tooth. This divides the surrounding tissue into very small pieces and at the same time blows them apart. Since explosion occurs in water, it is called as **"water–induced"** ablation. A water spray has to be used for cooling since some conduction of heat cannot be avoided. Through an adequate amount of spraying, thermal damage of the pulp can be avoided. The conduction of heat is highly dependent on the pulse duration and the form.

As a basic requirement, the preparation has to be performed with an optimized device using the "Method of minimal pulse energy" according to manufacturer's instruction. The reason is to work with the minimal potential of collateral damage **(Table 4.1)**.

Table 4.1

Er: YAG and Er, YSGG
– High superficial impact
– Low penetration depth
– High energy densities are applied to the tooth surface
– Very short application time (pulse duration = ms)
– Low increase in temperature

Surface Characteristics of Laser-prepared Cavities

The results of cavities prepared with Er:YAG and Er:YSGG lasers are very similar.

The cavity ground is observed to be rough and the ablation edge is uneven. The roughness of the site of fracture extends deep into the microstructure. Therefore, a large adhesive surface is available for bonding with filling materials.

The ablation edge in dentin is less irregular than in enamel because dentin is less brittle due to higher organic content. The dentinal tubules are also observed to be open. These open tubules offer a key for bonding between the restorative material and dentin.

The effect of erbium-based laser systems on dentin and enamel surfaces was shown in series of electron micrographs. The ablation with an Er: YAG laser was produced by a single pulse **(Figs 4.4A to D)**.

Overview of Ablation Crater of One Pulse in Enamel

An ablation crater of about 1 mm diameter was seen. The roughness of the cavity ground and the typical uneven ablation edge are easily visible. The sites of fracture follow the facets and edges of the enamel prisms. Through their irregular course the microretentive pattern of the laser cavity is produced in the enamel. The site of fracture extends into the microstructure. Therefore a large adhesive surface is available for bonding with filling materials. In the ablation pattern the typical shards of the enamel prism layers are clearly recognizable.

Fig. 4.4A: Preoperative photograph showing discolored enamel

Fig. 4.4B: Laser veneer and enamel modification – Laser Er:YAG, RO2 handpiece, 200 mJ , 30 Hz with water spray

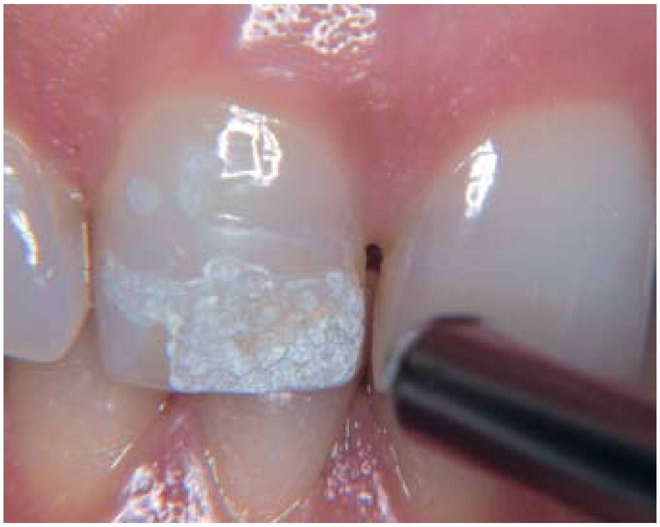


Fig. 4.4C: Ablated enamel

Fig. 4.4D: Postoperative view of the veneered tooth

(**Figs 4.4A to D:** *Case courtesy: Dr Anita Nitin, Vikram Perfect, Mysore, Karnataka, India*)

Overview of Ablation Crater of One Pulse in Dentin

The crater has a diameter of 0.8 mm. The roughness of cavity ground is easily visible, but in dentin the shard like character is missing. The ablation edge is less irregular than in enamel because dentin in less brittle. The open ends of the dentin tubules are clearly visible. The difference of density between the peri-tubular and inter-tubular dentin can be seen. The dentin tubules protrude in the preparation area like chimneys. The open dentin tubules offer for bonding between the restoration and dentin. The liquid bonding material can penetrate them deeply and form firm anchoring in the hard tissue of the tooth.

Overview of Cavity Preparation with Numerous Pulses

It leads from enamel into the dentin. The rough enamel area with shard-like delaminations is in the fore ground. The enamel dentin border is visible as a transverse crack across the back wall of the cavity. Through dehydration of the samples the dentin evaporates more than the enamel because of the higher percentage of water. Seperation of layers can be observed **(Table 4.2)**.

The ablation with Er, Cr: YSGG laser in the enamel and dentin

Principle is same for both Er: YAG and Er, Cr: YSGG lasers. Differences in the ablation quality and efficiency

Table 4.2

Impact on the pulp
Superficial absorption
– Localized temperature rise
– No thermal damage

of both device types are mainly due to the pulse form or the configuration of the sapphire tip.

Cavity preparation with numerous pulses in enamel

A micro-retentive pattern through the rupture along the edges of the prism is recognizable. Sharply defined border of the preparation are seen. It differs from Er: YAG cavity, in form from the shard lines of the enamel pattern.

Cavity preparation with numerous pulses in dentin

Open dentinal tubules are visible. The structure of the cavity surface looks different as the tubules stand perpendicular to the surface. The intensity on the surface decreases with the increase in the tip diameter, since the pulse energy spreads to a bigger surface.

The most obvious differences can be seen in the SEM-pictures with 500, 800 and 1000 μm fiber diameter. Ablating with the 500 μm tip causes the retention pattern to have smaller structures and to go deeper, whereas with the 800 and 1000 μm tips, the pattern is shallower and more even, which corresponds to the decreasing intensity.

Adhesion and Margin Seal of Laser Prepared Cavities

The adhesion of composites in laser prepared cavities and the quality of microretentive patterns through laser ablation are of significant importance for conservative dentistry.

The roughness produced with the laser at least equal that of acid etching. One of the study proved that the Er: YAG laser device produced minimal thermal induced changes of dental hard tissue compositions and did not cause changes in the ca/p ratio and knoop hardness compared to the bur cavities. Er: YAG laser is a pulp preserving hard tissue drilling tool when used with the specific energy settings and emitting radiation at a wavelength, λ of 2.9 μm.

The time taken to remove carious enamel by laser irradiation is slightly longer than with the rotary cutting device.

There is least microleakage of composite restorations when treated with lasers as compared to conventionally prepared cavities.

The irregular cavity surfaces prepared by Er: YAG laser affords better adhesion and sealing than those prepared by mechanical bur. A laxer marginal seal was found at restorations prepared with Er: YAG laser compared to conventional fillings in a color penetration test. The resin monomers can penetrate into open dentinal tubules and the subsequent polymerization results in formation of resin tags.

However, hybridization does not occur either for the dentin surface or for the tubule orifices. The Er: YAG laser is less effective on peritubular dentin and does not enlarge the tubule orifices.

When etching with 35% phosphoric acid gel applied to the irradiated dentin, the acid partially removes the highly mineralized peritubular dentin, decalcifies the underlying dentinal structures and opens the dentinal tubules, which acquire a funnel-shaped appearance.

The bonding agents should effectively seal the dentinal surface and the dentinal tubule orifices to prevent postoperative sensitivity and protect the pulp.

A high preparation quality is attributed to Er: YAG laser. The quality of filling therapy after Er: YAG laser preparation is equal to the conventional preparation techniques. A better marginal seal is obtained with the Er: YAG laser and composite fillings. Er: YAG laser can also be used for caries prevention. Due to significant temperature rise on the tooth surface, it is not recommended. To get an optimal marginal tightness, careful adaptation of the filling materials into the laser cavity should be done.

MECHANISMS OF ABLATION

The usual mechanisms that lead to ablation or decomposition of biological materials are photo chemical, thermal or plasma mediated. Photo chemical ablation is typical at very short wavelengths. Photo thermal ablation mostly refers to very high energy densities in the irradiated area and thus is very independent of the applied wavelength. Photo chemical ablation was not very effective in dental hard tissues for practical reasons.

The most commonly used laser systems for dental hard tissue removal are thermal pulsed ablation achieved by laser in the 3 μm range (i.e. Er: YAG and Er, Cr: YSGG lasers).

Generally, thermal ablation means that the energy delivered by the laser is coupled into the irradiated material by an absorption process yielding a temperature rise there.

Several consecutive mechanisms then lead to ablation. After a certain temperature is reached, melting, vaporization or sublimation of the irradiated material can be achieved that allows it removal. The removal is done either by ejection via expansion of the heated material or by applying an additional fluid set to blow it out. Depending on the material, or rather on constituents of biological tissues, different wavelengths and the most suitable laser has to be chosen.

The ablation process caused by pulsed laser radiation in the 3 μm range, the main absorbing constituent in hard dental tissue is the embedded water. Its maximum absorption peak in the infrared is situated around this wavelength and therefore fits exactly to the Er: YAG (λ = 2.94 μm) or Er, Cr: YSGG lasers (λ = 2.79 μm).

When irradiating dentin or enamel by a laser pulse with sufficient pulse energy, the water embedded in the tissue is heated up very rapidly above the boiling point. This causes a micro-explosion leading to mechanical decomposition of the tissue and blowing out of the generated small particles and spallation. In this way, an ablation threshold describing the minimal pulse energy for removal of material can be defined.

Mechanism of Absorption of Light in the 3 μm Range by Water

The energy absorbed by a certain material out of an irradiated beam very often is converted into heat. This especially applies to light in the IR range at energy densities that cause no nonlinear effects in matter. Matter can be brought into an excited state by energy transfers. The input energy is absorbed by the single atoms or molecules, which are able to store if for a certain time. In this state the particles have higher energy, i.e. they populate a higher energy level. The excited energy has to be similar to the energy differences b/w the two adjacent levels. The energy of the irradiating light is quantized. One quantum of light is called a photon. For an excitation the photon energy has to fit to the difference between two energy levels. As the photon energy is coupled to the wavelength, the ability for absorption for a certain matter depends on the wavelength of the irradiating light.

In the case of water, light is absorbed by the H_2O molecule, thereby changing its rotational and vibrational states. The increase of energy in the molecule leads to a change in the length and the eigenfrequencies of the – OH bonds. After a certain lifetime the molecule drops down again to its ground state and releases the absorbed energy. This action is called recombination.

Physical Factors Influencing Ablation Efficiency and Quality

Two main types:

- The material properties
- The properties of the irradiating laser light

1. Relevant material properties for biological hard tissues:
   - Co-efficient of absorption (α)
   - Reflectivity of the tissue surface (R)
   - Specific heat capacity (c_p) of the absorbing constituents in the tissue
   - Capability of heat conduction (Thermal diffusivity-k) in the tissue
   - Distribution of water within the tissue.
2. Properties of the laser light
   - Wavelength (λ)
   - Pulse energy (Ep)
   - Pulse duration (t_p)
   - Temporal beam profile (pulse shape)
   - Spatial beam profile (TEM modes).

The ablation efficiency and quality of ablation depends on the properties of the laser light.

1. Material properties

The co-efficient of absorption α (cm^{-1})

- It describes how strongly the radiation is absorbed in a medium
- The optical penetration depth is the reciprocal of the absorption co-efficient.

Reflectivity R (%)

It describes how much intensity is reflected at the interface between a material with low optical density and a material with high optical density.

The specific heat capacity cp(J/kg K) of a material describes the amount of energy it takes to heat up 1 kg of the material by 1° celsius.

It connects the laser energy deposited in the tooth to the temperature rise induced in the affected volume.

The thermal diffusivity k (cm^2/s)

It describes the capability of the material for heat conduction. It characterizes the velocity of heat flux.

Distribution of water in the tissue

It refers to the fact that for thermal ablation in the 3 µm range the main absorbing constituent is the embedded water. Its concentration plays an important role in ablation efficiency.

2. Properties of laser light

Pulse energy and pulse duration

- Pulse energy refers to the amount of energy provided by the laser pulse
- The required amount of pulse energy depends on several factors: size and specific heat capacity of the volume to be heated up
- The ablation threshold in terms of pulse energy is always a function of the duration as it describes the minimum energy that is necessary to cause ablation of the heated volume.

Pulse duration

- It describes the duration of a pulse
- Adjustable in time steps (s, ms) or time classes
- It significantly influences heat distribution in the tooth
- Plays an important role in ablation efficiency and quality.

Pulse repetition rate (PRR)

- It describes the number of pulses per second.

Distribution of water in the tissue

It is one of the most important factor for ablation efficiency. Tissue layers with less embedded water will yield less ablated volume per unit time in the 3 µm range. This is the reason why enamel needs much more pulse energy than dentin for acceptable processing speeds. The water content of healthy enamel is about 12 vol % healthy dentin about 24 vol%. The water content of carious tissue is much higher than in healthy tissue **(Table 4.3)**.

Table 4.3

Limitations of water mediated ablation
Pulse energy
- If too high, it results in crack formation in the residual tissue
- Pain
- Overheating of the pulp
Pulse duration
- Optimum 0.5 µs for good spatial confinement of the energy
- Pulse shape should be near to the optimum
- Usually pulse duration ~ 150 µs → massive heat transfer
Excessive heat transfer
- Overheating of the pulp
- Incomplete spallation in lower regions
Adjustable parameters
Pulse duration
Pulse energy
Water spray on / off or amount of water and air
Non adjustable parameters -----> pulse shape

Criteria for Optimized Laser Systems in Hard Tissue Ablation

- Application of very short pulse durations to achieve the spatially best possible confined energy distribution
- The rise in pulse time also plays a very important role for the spatial confinement of energy in the tissue
- A low pulse energy is possible (Method of minimal pulse energy)
- Good pulse shape
- Optimized water spray for cooling
- The most important influence factor for a good ablation quality: The user himself has to have adequate knowledge of the right pre-requisites to perform well on the patient.

Requests for Improved Ablation Techniques and Laser Systems

Most important concern is to perform ablation with the lowest possible energy and with pulses as short as possible to induce the lowest possible collateral damage.

The systems available today exceed the maximum allowed pulse length $T_p \leq T_{rel}$ sometimes by 300–400 times (150 – 200 µs instead of 0.5 µs).

The thermomechanical ablation process applied until now can be regarded to be part of the "limiting problem" for reliably damage – free preparation of teeth. Hence another kind of ablation process that must be able to ablate the material via direct impact on hard tissue components without generating thermal damage has to be found.

The ideal process for dental hard tissue ablation should have the following properties:

- No crack formation in the remaining tissue
- No heat transport into the residual tissue
- No shock wave delivery into the tooth
- No adverse effect of heat or high energetic radiation on the pulpal soft tissue.

ABLATION WITH LOW COLLATERAL DAMAGE

There are two other mechanisms of ablation that can be used for precise material removal

- Ablation by excimer lasers with wavelengths in the ultraviolet range
- Application of ultrashort laser pulses in the near infra red region.

Ablation with excimer lasers was found to be unsuitable for dental hard tissue treatment, because

1. They have low ablation rates per pulse together with very low repetition rates.
2. High costs of purchase and operation.
3. Complicated handling and maintenance.
4. Carcinogenicity of several UV wavelengths.

Ablation by Ultrashort Laser Pulses – from Thermal Ablation to Plasma Mediated Ablation

This relatively new technology bears a high potential for a fast, precise and nearly damage free material processing and also broad industrial applications.

Ultrashort laser pulses are pulses with duration in the time regime of several tens of Ps (Picoseconds) down to some fs (femtoseconds) or even below.

1 ps = 10^{-12} s

1 fs = 10^{-15} s

The ablation threshold of a material falls significantly with decreasing pulse length. Less energy per pulse has to be applied to cause ablation. There is less energy to produce collateral damage.

Ultrashort pulses are very interesting to use for the treatment of biological tissues where only small or even no heat affected zones can be tolerated (e.g. neurology, ophthalmology and preparation of teeth).

The decrease of the ablation threshold at short pulse lengths is caused by the high power densities that can be achieved. The shorter the duration of a pulse with a certain pulse energy can be made, the higher is the achievable peak power of the pulse. If these high peak powers are combined with a sufficient focusing of the beam, very high power densities can be generated at an irradiated surface.

Thus, an ablation mechanism completely different to the thermomechanical stress generation occurs: the plasma mediated ablation. In this intensity the power generated on the surface are so high that non-linear processes are initiated. This allows the generation of the thin layer of plasma in the irradiated zone. This plasma layer absorbs nearly all the energy contained in the laser pulse.

According to the laws of thermodynamics, the plasma expand rapidly and blows itself out. Since the pulses are so short; there is nearly no time for heat to flow into surrounding lattice, as the irradiated energy is "switched off" again.

Plasma Formation and Ablation of Material

Power densities > 10 W/cm^2 are obtainable with sufficient pulse energy and focusing conditions. An electric field of about 10^7 V/cm can be generated at the focus spot. A microplasma is induced with an absorption co-efficient much higher than that of enamel. The laser beam is absorbed totally by the plasma. The ablation itself is caused by the ionization of the enamel and the shock wave generated by this.

Advantages of this interaction mechanism are the low thermal effects and the lack of crack formation in enamel. The initiation of the plasma development is driven by multiphoton absorption (MPA). The irradiation intensity is so high that the valence electrons of the atoms in the affected matter can absorb two or more photons at once. Hence they gain enough energy to leave the atom, thus creating plasma.

The generated free electrons are further accelerated by the absorption of the incident light. On their way through plasma they collide with other atoms and transfer a quantum of their energy to them. Hence additional free electrons are produced. This process is called 'Impact ionization'.

MPA is the dominant process during the leading edge of the incident light pulse. The plasma is heated up rapidly as the free electrons absorb part of the light pulse. The heating of plasma leads to its expansion and it is blown out easily as the ions and free electrons to overcome the material bonds. Hence the matter is ablated and all the energy during plasma mediated ablation is absorbed in a layer of about 1 μm thickness.

Benefits of Ultrashort Laser Pulses

- Plasma mediated ablation is very suitable for surgical procedures where the highest degree of precision with a nearly complete absence of collateral damage has to be achieved.
- Suitable for the treatment of lesions in dental hard tissue.
- The bottom and the walls of the cavity produced show a microretentive pattern and exposed dentinal tubules.
- The complete absence of a smear layer could allow a direct application of composite materials without etching.
- It is also possible to produce minimally invasive cavities in which only carious tissue is ablated.

This natural given selectivity can be further supported and controlled by spectral analysis of the generated plasma sparks. Spectral analysis as a standard measuring method allow a reliable diagnosis of the treated tissue. It allows the precise diagnosis and treatment of the well known "white spots kept under observation" at an early stage.

Limitations of ultrashort pulse laser systems

Their size, their sensitivity to environmental changes and their high price are limitations of ultrashort pulse laser systems **(Fig. 4.5)**.

Fig. 4.5: Erbium hand piece

OTHER TYPES OF LASER

CO_2 Laser

The CO_2 laser was investigated very early for dental hard tissue removal, as it was one of the first available systems with a sufficiently high output power. The wavelength of the CO_2 is absorbed much better in collagen than in water. It seems to be evident that the interaction cannot avoid direct heating of the tissue. The usability of the CO_2 wavelengths in hard tissues will always be limited due to the uncontrollable temperature rise induced.

Nd:YAG Laser

This is less absorbed in dental hard tissue, thus having a high penetration depth. Heat can be transported easily to deeper layers, including a profound heating of large volumes. The Nd: YAG laser has to be classified as not suitable for caries removal, because it bears high risk of pulpal damage due to high penetration depth and the additional heat transport deeper into the tooth.

Ho:YAG Laser

In the beginning, it was believed to be suitable for dental hard-tissue substance removal. But later significant collateral heat damage was found. Inspite of this, it is much appreciated for surgical applications by users due to its low penetration depth **(Table 4.4)**.

Table 4.4

Indications
Conventional cavity preparation (Class I – V)
Esthetic dentistry
Removal of filling materials (No metals)
Fissure sealing

PRACTICAL PROCEDURE IN LASER-ASSISTED CAVITY PREPARATION

- Application of the rubber dam
- Display of the cavity
- Removal of caries
- Finishing and restoration of the cavity.

Application of the Rubber Dam

Laser supported cavity preparation should be always with the use of rubber dam. It facilitates good view and use of other materials. Iatrogenic damage of the bordering approximal area can be avoided because of the low absorption by the rubber dam of the wavelengths used. The adhesive systems used with composite fillings provide a strong bandage under optimized dry conditions.

Display of the Cavity

Oral prophylaxis has to be done before the cavity preparation because the debris can influence the absorption of the laser. All safety requirements has to be checked (safety goggles, secured working area, a check of the laser parameters). The carious lesion is prepared first. The parameters recommended for enamel preparation by the manufacturer are used **(Fig. 4.6A)**.

The laser beam should be perpendicular to the tooth surface and under water cooling. A strong water spray is important under permanent suction. In the first working step, overhanging enamel areas are removed to allow access to the caries-damaged enamel and dentin.

Depending on the systems used, one works

- contact free with a visible laser spot or
- With contact supported through a stiff laser fiber.

In any case, one should work in contact free mode using free beam handpieces and a working distance has

Fig. 4.6A: First preoperative photograph showing proximal caries in relation to 1st and 2nd premolars

Fig. 4.6B: First premolar cavity prep settings: Laser Er:YAG, VSP 300-600 mJ, 20-30 Hz, RO2 hand piece

Fig. 4.6C: First premolar restored with light cure composite resin

(**Figs 4.6A to C:** *Case courtesy: Dr Anita Nitin, Vikram Perfect, Mysore, Karnataka, India*)

to be observed that assures the smallest possible diameter of the aiming laser beam. Hand piece with a sapphire tip has to be guided over the working area at a distance of 1 mm. Thus, fiber will not get stuck on the surface and facilitates sufficient cooling. Premature erosion of the fiber tip due to the annealing of adhered ablation particles can be avoided.

Removal of Caries

It is recommended to reduce the power of the laser while breaking through the enamel. On one hand, the thermal exposure of the pulp is reduced and on the other the removal of the carious dentin through lower energies is possible since the greater proportion of water in the damaged dentin causes a high ablation rate **(Fig. 4.6B)**.

With scanning of the carious area, a partly selective preparation is done under spray cooling and suction cleaning. The energy of the system has to be reduced according to the distance of the cavity to the pulp during caries excavation. During preparation close to the pulp, the work should be intermittent and the frequency reduced. Total removal of caries is controlled with the classic probe test or with the help of a caries indicator. On closer inspection, the laser prepared areas are seen to have a matt surface that comes from the specific reflection-poor retention pattern.

Finishing and Restoration of the Cavity

A possible finishing and beveling of the cavity mainly depends on the choice of the filling material. Finely tapered enamel lamellae are removed with a carbide finishing bur or with an Arkansas stone **(Fig. 4.6C)**.

After a careful cleansing of the cavity with a water spray and alcohol, the adhesive can be brought in and the composite filling can be finished. Acid etching generally not necessary as the laser preparation leaves a microroughness that is at least equal in adhesive power to the retentive pattern produced by etching with phosphoric acid. If adhesive materials are not used, the same working steps as in conventional cavity preparation have to be followed **(Figs 4.7A to C)**.

CHOICE OF PARAMETERS

The choice of the correct parameters is strongly dependent on the actual laser system applied. The parameters

Fig. 4.7A: Preoperative photograph showing fracture of the incisal edge

Fig. 4.7B: Settings: Laser Er:YAG, VSP 300-600 mJ, 20-30 Hz. For denitin prep- VSP 150-200 mJ, 10-20 Hz, RO2 handpiece

Fig. 4.7C: Postoperative photograph showing restored incisal edges

(**Figs 4.7A to C:** *Case courtesy: Dr Anita Nitin, Vikram Perfect, Mysore, Karnataka, India*)

have to be kept as low as possible in order to minimize the risk of collateral damage. In general, it can be said that the highest pulse energies can be used for the ablation of enamel. When the preparation advances into the dentin, the output power can be reduced by one-third and close to the pulp, it should be further decreased. The same holds true for the removal of resin or glass ionomer fillings. If the surface should only be cleaned or roughened, the power can be reduced even when working within enamel **(Tables 4.5 and 4.6)**.

Table 4.5

Advantages of laser-assisted cavity preparation
– Selective caries removal
– Preservation of pulpal tissue
– Well tolerated by patient
– Restitution of shape and function

Table 4.6

Disadvantages of laser-assisted cavity preparation
– Crown / bridge techniques are not feasible
– Removal of dental alloys or amalgam are not possible
– Longer treatment time

CHAPTER

5

Photo Polymerization

- Introduction
- Photo Polymerization Reaction
- Laser Photo Polymerization Versus Traditional Methods
- Factors Associated with Photo Polymerization
- Clinical Procedure of Photo Polymerization by an Argon Laser

INTRODUCTION

The treatment of carious lesions has always been accompanied by the search for the ideal filling material. Modern dentistry approaches a dental lesion as conservatively as possible. Minimally invasive techniques are the result of decades of developing new materials and products for tooth restoration. Chemically cured materials were replaced by UV curing and later by visible light curing materials.

The 1990s saw the evolution of effective caries prevention techniques and a range of new technologies to treat dental defects and lesions. These include air abrasion, the chemical dissolving of caries and laser techniques such as PAD (Photo Activated Disinfection), caries diagnosis by laser fluorescence, caries prevention by laser irradiation and laser cavity preparation.

Composition of Light Cured Filling Materials

Restoration in the frontal teeth region and small occlusal fillings or fissure sealings represents the ideal indication for light cured composite materials. Direct light cured restorative materials offers many benefits when compared to silver alloys and indirect restorations.

The most important benefit is preserving the tooth structure which can be bonded to the tooth restorative material with a tight seal. Additional benefits include excellent esthetics and the extensive field of applications. A decreased stability against masticatory pressure when compared to silver alloy, is an important factor to be taken into consideration.

There is wide range of light cured filling materials. They consist of three basic substances:

- An inorganic or filler phase
- An organic or matrix phase
- A coupling or binding phase.

Filler Phase Components

Either crystalline quartz (SiO_2) or heavy metal glasses (lithium aluminium silicate, borosilicate) are used to make the filling material radiopaque. They are usually rounded and less sharp. Classification is based upon the particle size and mode of distribution.

Matrix Phase

Matrix phase contains three different groups of components:

Firstly oligomers such as BIS-GMA or Bowen resin monomers like TEG DMA are most commonly used. Monomers like TEG DMA and BIS-GMA are added which regulate viscosity and have more superior color stability. Their main drawback is that they increase polymerization shrinkage. Secondly, a photo-initiator, mostly Camphoroquinone followed by benzylperoxide or benzoylalkyls ethers are used. Thirdly photo-inhibitors, like hydroquinone monomethyl ether are used to prevent polymerization during storage.

Several components are added to enhance the esthetic and tooth like appearance of the filling materials. They are color pigments and stabilizers, UV absorbers and modulators of fluorescence.

Bonding or Coupling Phase

It consists of an organosilane that surrounds the filler particles and creates a bond between the filler and the matrix phase.

The clinical behavior of a composite filling largely depends upon the polymerization reaction inside the material. Poor polymerization leads to an insufficient conversion rate. As a result, restorations have weaker physical properties, less wear resistance and increased moisture absorption and discoloration. Less adhesion to enamel and dentin leads to increased microgap formation and microleakage leading to bacterial invasion, pulp irritation and secondary decay.

Effective polymerization requires

1. Quality and quantity of the energy delivered by the light source.
2. Incremental filling technique.
3. Correct light exposure time.
4. Correct distance from the light source to the material.

PHOTO POLYMERIZATION REACTION

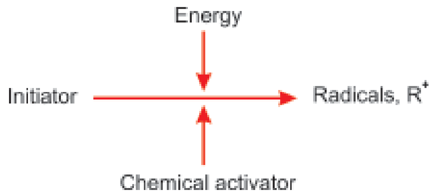
Polymerization is always initiated by free radicals **(Flow chart 5.1)**.

Chemical polymerization and polymerization by UV light are no longer used because of several disadvantages compared to visible light curing.

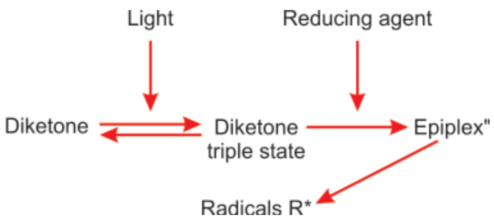
Photo polymerization or visible light curing occurs when free radicals are formed from a diketone and a reducing agent during light exposure **(Flow chart 5.2)**.

The most commonly used photo-initiator or diketone is Camphoroquinone. It absorbs the radiation energy and

Flow chart 5.1: Schematic representation of the formation of radicals by different types of initiator system



Flow chart 5.2: Free radicals formed from a diketone and a reducing agent during light exposure



is transferred to excited states. At the appropriate excited state (Triple state), it combines with the photo accelerator or reducing agent to form a complex in an excited state (Epiplex) which breaks down to give reactive free radicals. These free radicals trigger the polymerization reaction they first react with the oxygen on the surface layer and the added photo inhibitor. Then they affect the oligomers and monomers present in the materials, to form chains of polymers and crosslinking. A free radical (RAD) stabilizes by giving its superfluous energy to a target molecule which has at each of its ends a double bond (c = c). As a result, an electron out of the p-orbital of those double bond is released, with the creation of a new free radical, affecting another oligomer or monomer and thus creating chains of polymers. The formation of long polymer chains and a high degree of crosslinking is ideal. The aim is to produce a high conversion rate, and this is dependent on the quality and quantity of available light energy.

LASER PHOTO POLYMERIZATION VERSUS TRADITIONAL METHODS (FIG. 5.1)

Photo polymerization starts when radiation energy is absorbed by a photo initiator or diketone. Camphoroquinone is most commonly used. It has an absorption spectrum between 460 and 492 nm with a peak at 468,

$$\lambda_{max} = 468 \text{ nm}$$

Halogen lamps show the broadest spectral emission from 300 to 1300 nm. Wavelengths beneath 400 nm and above 500 nm have to be filtered out, because only wavelengths between 400 and 500 nm produces useful energy for photo polymerization.

Beneath 400 nm – possibility of potentially dangerous UV light.

Above 500 nm – possible heating and pulp damaging infrared light.

Intensity output range between 400 and 600 mW/cm^2.

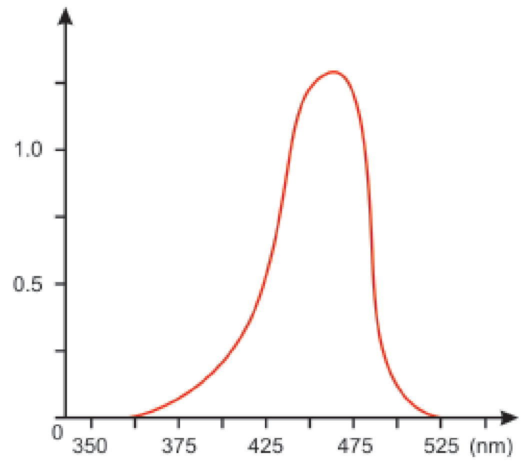


Fig. 5.1: Camphoroquinone absorption coefficient curve (According to Cipalla)

Latest devices can generate upto 1000 mW/cm^2. Plasma arc devices have the same spectral emission but different relative intensities at different wavelengths. Argon gas or xenon gas are used to generate the light energy. The argon device filters out wavelengths beneath 445 nm and above 505 nm. The xenon type filters out wavelengths beneath 430 nm and above 500 nm. Energy densities range from 1600 to 2000 mW/cm^2.

LED's or indium-gallium-nitride light emitting diodes, generate a smaller emission spectrum with a peak around 470 nm.

Argon laser produce a limited number of very specific wavelengths (λ) of light energy with 476 nm, 488 nm and 514.5 nm the most important. It can also produce extremely high energy densities. Because laser light have unique properties, all the features add benefits to Argon laser photo polymerization. The unique wavelength of 488 nm provides important energy because it is in the maximum absorption range of camphoroquinone. It has a high penetration depth and an excellent diffusion

Table 5.1

Important features to be noted when curing with an Argon laser
– The reduction in polymerization time
– The quality of the polymerization reaction
– The pulpal response
– The physical properties of the cured materials
– The management of the inherent polymerization shrinkage
– Caries prevention action

throughout the composite layer. The thin delivery fiber of 300 μm gives easy access to every region in the mouth. Energy densities do not decrease with increased distance from the target material. Power output and energy densities are adjustable and controllable **(Table 5.1)**.

Only 1/3 of the power output provided by conventional light sources is really influencing and activating the photo initiating system of light cured materials using Camphoroquinone as a photo-initiator. They emit incoherent light and is therefore out of phase with different waves overlapping each other, thus reducing each other's photon energy or even neutralizing each other.

Laser light is coherent and monochromatic. Hence, the photons do not interact with each other and all the energy produced by the 488 nm wavelength is capable of interacting with the Camphoroquinone molecules present in the target material. The efficient initiating process induces an equal chemical response leading to a reduction in exposure time. All composite resins use Camphoroquinone as a photo-initiator and are thus capable of being light cured by the single wavelength energy of a laser.

The energy flux or the amount of energy developed depends on the average power output, the time of interaction and the area of exposure.

$$E = \frac{W \times S}{cm^2}$$

E = Energy flux
W= Watt
S = Second

The different chemical constitutions of the light cured materials make them respond differently to a given energy flux, and within it, to variations in time and power settings. Laser devices permit these precise and controllable settings and provide optimal polymerization for the material to be handled.

The general consensus is that laser exposure time should be 25% of the recommended time for VLC devices and with average power settings of 350 mW. The higher the laser power output, the faster polymerization takes place. But above a certain threshold, there is an equal decrease in the quality of the polymerization. Besides an increased reaction speed with decreased exposure time, polymerization is accomplished more efficiently resulting in a higher conversion rate.

Visible light curing (VLC) provides lower conversion rates compared to laser curing, achieving cured materials with fewer residues. These residues may be potentially dangerous when leaking to the pulp or to the oral environment. Another concern for the vital pulp is an increase in temperature while curing. The critical threshold is 5.6°C, with temperature increases above this causing irreversible damage to the pulp. The energy densities generated during laser curing did not affect the pulp or the surrounding enamel. The highest surface temperature of the cured resins was 13.8°C which was due to exothermic polymerization reaction and the light energy.

Fig. 5.2: Example of Argon laser unit

The degree of polymerization was measured, comparing Argon laser to VLC. A significant difference was noted in Brinell hardness in favor of Argon curing and with 1/3 of the exposure time Argon 10s vs VLC 30s **(Fig. 5.2)**.

The Argon laser also has a higher penetration depth in the cured resin layer and produces better physical properties. The higher energy density combined with the ideal wavelength produced by an Argon laser, improves the hardness of cured resins, increases the polymerization rate with improved compressive and tensile strengths and reduces the shrinkage stress at the interface. The adhesion to dentin and enamel is proportional to the energy flux applied. These features show less pulp irritation and less postoperative sensitivity.

Curing 3 layers of composite material for 40s with a halogen light and with an energy density of 400 mW/cm^2 produces a total energy flux of 485 J/cm^2.

Using an Argon laser at 1000 mW/cm^2 for three passes of 10s generates a total energy flux of only 30s J /cm^2. The compressive strength measurements show higher values after laser polymerization than VLC and with reduced exposure times. The tensile strength are also higher after laser polymerization and with a total exposure time ¼, compared to VLC. They indicate a higher resistance to lateral tensile forces during function. Transversal flexural strength values are in direct correlation with the resistance to distortion of the material when loaded. The flexural modulus indicates the stiffness or rigidity of the cured filling materials.

If the filling material shows a lower flexural modulus, it will be compressed more than the surrounding tooth structures during chewing. This causes high tensile forces and shear stresses to the tooth filling interface, with fractures in the marginal seal, microleakage and secondary decay formation.

Laser polymerization increases the values of the flexural modular. The higher degree of conversion rate with a more profound polymerization and the decrease of the remaining unpolymerized monomer produces enhanced physical properties after laser curing. The conversion rate will affect chemical stability as well as fatigue wear in light cured materials.

Wear rate and resistance to wear are important features in predicting the clinical behavior of composite resin restorations. Abrasive wear occurs when a hard surface slides against a softer one and is related to the friction between two sliding bodies, called 'two body abrasive wear'. Erosive wear occurs when a medium containing hard abrasive particles lies between the sliding surfaces and causes three body abrasive wear or erosive wear. Corrosive wear is the result of a chemical reaction. In composites, moisture absorption leads to corrosive wear. Fatigue wear results from repeatedly overloading the surface beyond its elastic limit. With brittle materials, particularly, this can lead to crack formation, as the material just below the surface is usually strained to a higher extent than the surface itself.

The homogeneous penetration of the laser light induces an improved marginal seal due to reduction of the shrinkage stresses towards the light source. The superior polymerization induced by the energy of a laser improves bond strengths to enamel in primary teeth as well as in permanent teeth. Bond strength to dentin is highly dependent on the energy density generated by the light source and the wavelength, which should ideally be as close to the λ_{max} of Camphoroquinone as possible. There is little to no effect evident in changing the distance from the fiber tip to the resin surface while laser curing.

This is contrasted with LC, which shows a significant decrease in bond strength from increasing the distance from the light tip to the resin surface. The polymerization shrinkage is inherent in all light cured materials and is dependent on the organic and inorganic phase ratio. There is reduction of the polymerization stresses toward the light source when using an Argon laser for photo polymerization and also an increased filler phase decreases shrinkage. VLC and laser curing cause the same amount of polymerization shrinkage at any given rate of conversion.

The higher the conversion rate, the more monomers and oligomers have interacted with equally increased shrinkage but with improved physical properties and reduced cytotoxicity. Laser curing shows a higher conversion rate. In chemically cured materials, polymerization shrinkage is directed towards the center.

Incremental curing reduces, but does not completely eliminate the gingival contraction gap. It shrinks towards the light source because the composite closer to the light hardens first. This, in turn, pulls the softer composite resin from the gingival areas creating a gap **(Fig. 5.3)**.

The homogenous penetration of the resin by the laser beam should result in improved marginal integrity by reducing the amount of polymerization shrinkage toward the curing light.

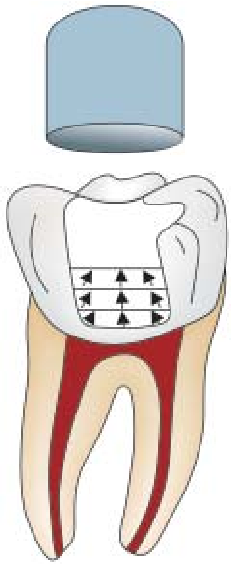


Fig. 5.3: Direction of polymerization shrinkage of composite resin towards the light source in visible light curing

Laser curing gives a uniform and immediate penetration of the light energy into the composite mass as a whole. Polymerization starts at the same time in every portion of the composite layer, on the surface as well as on the bottom. Thus, the shrinkage is directed to the adhesive layer on the cavity wall and on the bottom, resulting in an improved integrity at the interface and an improved marginal seal. The higher the energy density of the light source, the less polymerization shrinkage stress occurs **(Fig. 5.4)**.

Fig. 5.4: Direction of polymerization shrinkage of composite resin away from the laser source in incremental laser curing

Through the generation of a higher concentration of reactive camphoroquinone radicals, the start of the polymerization reaction yields more and shorter polymer chains, with increased flow and elasticity in the material during the initial polymerization process.

Cavity design is another factor of influence. There are many factors involved during the polymerization process that may affect the resulting shrinkage stresses and their impact upon the integrity of the tooth restoration complexes. It is very difficult to prove that effective reduction in overall shrinkage stress, and hence, deformation of the remaining hard tissue walls are sufficient reasons to prefer incremental filling over single bulk filling. Laser curing used with technique of single bulk filling may improve the toughness of cure and bond formation.

Improved Clinical Performance of Laser Cured Materials

Laser light is able to change the morphology of enamel, dentin and cementum giving increased resistance to acid solubility. The light energy of an Argon laser is highly efficient for this purpose, with the additional benefit of being pulp friendly. The low energy densities are below the threshold energy density for photo polymerization. A caries preventive effect occurs during laser curing. There is also an increased affinity to calcium, fluoride and phosphate ions.

The conditioning of the enamel surface during Argon laser irradiation facilitates the uptake of fluoride, producing an improved reduction in demineralization after an acid attack.

Curing sealants with Argon laser energy produces the beneficial effects of reduced solubility of the surrounding enamel and decreased microleakage. An additional feature of the light of an Argon laser is early inter-proximal caries detection. Decalcified areas appear as dull, opaque, orange colored zones. Even the appearance of enamel fractures can be detected.

FACTORS ASSOCIATED WITH PHOTO POLYMERIZATION

Argon laser curing of light activated materials adds substantial benefits to the clinical behavior of tooth restorations in time. It allows the practitioner a more relaxed, but secure and safe way of operation. Argon laser as curing device has a limited spectral emission which is of concern.

Besides camphoroquinone (CQ), other photo initiators can be used to induce photo polymerization. Due to the slightly yellow color of camphoroquinone (CQ) phenyl propanedione (ppd) or lucerin TPO (L TPO) may be used, especially when dealing with very light colors of composite materials such as the special “Bleaching colors”. Those photo initiators have different spectral requirement than camphoroquinone. The spectral emission of an Argon laser overlaps the absorption of PPD only in a limited way. But does not overlap all nor is congruent with the absorption range of LTPO.

Before using an Argon laser as curing device the manufacturer’s instruction for use have to be consulted to be sure the product’s spectral emission for photo polymerization (SE) and the energy density for optimal polymerization (EOP) at a specific depth (D) are congruent with the features of the laser used.

The “conventional VLC” devices are being replaced by “improved” ones with increased power and energy densities. All halogen light based curing devices decreases the energy output with time even with improved devices and a proper radiant exitance meter has to be used regularly to measure the real irradiance (W/cm^2). Plasma lamps with a narrow bandwidth were followed by plasma lamps with broader bandwidth to overcome the problem of insufficient spectral emission.

The problem with all plasma lamps is that they generate an improper polymerization at the curing times recommended by the manufacturer resulting in a conversion rate far too low and an insufficient Vickers hardness at depth.

The first generation of LEDs has a limited spectral emission and the energy densities they could generate were too low. The next generation of “Super LEDs” dealt with the problem of insufficient power output. The latest generation of super LEDs with a broad bandwidth incorporate two types of diodes with different wavelength peaks, designed to activate separate photo-initiators and produce proper polymerization in depth.

CLINICAL PROCEDURE OF PHOTO POLYMERIZATION BY AN ARGON LASER

- Photo polymerization of light cured dental materials by means of an Argon laser provides superior clinical results.
- Failures due to improper clinical handling or technical problems are reduced.
- The technique offers a reduction of 75% in curing time.
- The distance to the light source is not as critical as compared to VLC.
- The energy flow is controllable and adjustable.
- The physical properties of the light cured material are improved
- Reduced pulp irritation and low postoperative sensitivity.
- Better management of the inherent polymerization shrinkage with an improved adhesion and marginal seal.
- Decay prevention properties of an Argon laser are significant.
- Good access to the material to be polymerized is a critical prerequisite when using VLC.

While curing with visible light, not only the distance of the light source to the surface to be polymerized but even the angle of the light source to the filling is important.

Due to a limited penetration depth of this multi-wavelength energy source, the conversion rate of the filling material decreases when depth increases.

The thin delivery fiber of 200 or 300 nm, the small sterilizable handpiece and the disposable flexible tips of a laser device, allow easy access throughout the various regions of the mouth. It may counteract these limitations of VLC devices, plasma lamps, PACs and LEDs. The easy access, together with the higher penetration depth of this single wavelength energy source, enables polymerization through enamel and dentin layers.

The tip diameter of conventional curing devices determines the number of curing cycles required for the full coverage of the surface of a composite layer.

The spot size of a laser device is adjustable making it possible to access the depth of a distal interpromixal cavity and as well as the full labial surface of the upper front teeth, thus, eliminating the need for multiple curing cycles, and an extended number of light guides.

Bracket bonding can be achieved by a lateral exposure, with an immediate and superior bond and a decrease in acid solubility of the surrounding enamel, and an equal prevention of the appearance of white spot lesions.

CHAPTER

6

Dentin Hypersensitivity

- Introduction
- Conventional Treatment Methods
- Laser Application in Treating Dentin Hypersensitivity
- CO_2 Laser
- Clinical Procedure

INTRODUCTION

Exposure of dentinal surfaces to oral and external fluids causes dentin hypersensitivity. If the dentin surface has been exposed, the dentinal tubules, which are open to the oral cavity and the pulp cavity, provide a connection between the oral environment and the sensitive nerve endings of the tooth pulp. Several stimuli can cause unpleasant sensations on exposed dentinal surfaces.

Dentin hypersensitivity is characterized by short, sharp pain arising from exposed dentin in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental effect or pathology **(Fig. 6.1)**.

Fig. 6.1: Schematic representation of cervical recession causing hypersensitivity

Causes

Exposure of dentin results from one or two processes:

a. Removal of enamel covering the crown of the tooth
b. Denudation of the root surface by loss of cementum and overlying periodontal tissues.

Removal of enamel may result from attrition relating to occlusal abnormalities, tooth brush abrasion, dietary erosion, habits or combination of these factors. There is increased incidence of gingival recessions with advancing age, chronic periodontal factors and certain forms of periodontal surgery. Sensitivity can also be experienced after scaling and root planning.

Hypersensitive teeth demonstrate twice as wider tubular diameters than those of nonsensitive teeth **(Table 6.1)**.

Table 6.1

Aim of the therapy
Closure of dentinal tubules ↓ (leads to) Interruption of the transmission of stimuli

Theories of Dentin Hypersensitivity

Hydrodynamic Mechanism

- Most widely accepted theory
- Transmission of stimuli to the pulp is by hydrodynamic mechanism
- Rapid movement of fluid within the dentinal tubules
- Fluid is extracellular and wall of dentinal tubule is more mineralized than the rest of the dentin
- Pain is produced by the rapid displacement of tubular contents at the pulp dentin border as opposed to the slow outward fluid flow
- Pain-producing stimuli create an outward fluid flow in tubules of 2-4 mm/s

Dentinal Receptor Mechanism

It implicates that the odontoblast has a special sensory function. The functional complex with the nerve ending in or near the odontoblastic layer acts as an excitatory synapse. The odontoblast and its process has been perceived as a transducer mechanism.

Modulation of Nerve Impulses by Polypeptides

- Plasma kinins (Kallikinins or Bradykinins) and substance P have been postulated as modulators of nerve impulses in the pulp.
- These substances may selectively alter the permeability of the odontoblastic cell membrane so that pulp neurons are more prone to discharge upon receiving subsequent stimuli.

Natural Pulpal Defense Mechanisms

The pulp has several natural defenses to protect itself from irritating stimuli.

Calcification

- The tooth may naturally desensitize itself with a peritubular dentin mineralization.

- Pulpal calcification, formation of secondary dentin and dentinal sclerosis has been demonstrated. This natural occlusion of the peritubular dentin by calcium crystals is the tooth's physiologic response to dentinal sensitivity.

Bacterial Plaque

- Another defense mechanism that may decrease sensitivity is the formation of plaque in the acquired salivary pellicle material coupled with salivary occlusion.

Sclerosis

The sclerotic zones beneath the region of attrition are occluded by peritubular, dentin-like material **(Table 6.2)**.

Table 6.2

Causes of dentinal hypersensitivity	
a)	Incorrect oral hygiene technique (e.g. Toothbrush abrasion)
b)	Poor plaque control (acidic bacterial byproducts)
c)	Exposure to acids (e.g. Sodas, fruit juice, wine)
d)	Cervical erosion
e)	Gingival retraction
f)	Malocclusion
g)	Iatrogenic (Scaling, root planing)
h)	Excessive (home) bleaching

CONVENTIONAL TREATMENT METHODS

In 1935, Grossman suggested the following requirements for a satisfactory material for the treatment of dentin hypersensitivity

- Nonirritant to the pulp
- Relatively painless on application
- Easily applied
- Rapid in action
- Effective for a long time
- Without staining effects
- Consistently effective.

Common Agents

Strontium

- 10 % strontium chloride hexahydrate dentifrice is used which only slightly reduces dentinal fluid flow due to occlusion of tubules by abrasive fillers.
- Strontium penetrates all calcified tissues including dentin hence it affects hypersensitivity by blocking the outer organic matrix of the root surface.

Sodium Monofluorophosphate (MFP)

MFP–enamel interaction shows the formation of fluoride hydroxyapatite without calcium.

Sodium Fluoride

- Various forms of fluoride are used for the treatment of dentinal hypersensitivity.
- Topical fluoride most likely results in the formation of a fluoride hydroxyapatite.
- The fluoride ion decreases the diameters of the dentinal tubules.
- It also encourages formation of a harder, more insoluble dentin which is more durable and protective.
- Fluoride containing medicaments do alter fluid flow and provide a benefit in the treatment of hypersensitivity.

Calcium Hydroxide

- It has been widely used below restorations. It has little or no effect on dentinal sensitivity
- Its long term effectiveness is attributed to the ability to cause increased peritubular dentin mineralization.

Formaldehyde

- There was reduction in sensitivity when formalin was incorporated into a dentrifice.

Resins and Adhesives

- An immediate and long lasting blockage of sensation was demonstrated after sealing the tubules or impregnating them with an unfilled resin or dentin – bonding material.
- Light–cured dentin bonding agents adhere better to tubular wall and dentin surface.
- After 18 months, a lasting effectiveness of 89-90% is found.

Glass-Ionomer Cement

- Due to its excellent adhesion to the tooth structure it can be placed without mechanical tooth preparation.
- It does not require etching.
- The material is hydrophilic and has good mechanical strength and adhesion.
- It is esthetic and appears to be nonirritating to the pulp.

Bio-active and Biocompatible Glasses

- Glasses can induce or aid osteogenesis in physiological systems.
- Particulate glass has been used for periodontal osseous repair.
- It has the capacity to bond with bone tissue and enhance growth by its osteoconductive properties.
- The formation of silicarich layer during interaction together with small size of bioactive glass particles enabled as a possible desensitizing agent for reduction of dentin sensitivity.

Oxalate Containing Products

They interact with the dentin surface, producing precipitates of calcium and phosphate with the potential to aid tubule occlusion.

Conventional treatments have long-term effects only through repeated or permanent application.

LASER APPLICATION IN TREATING DENTIN HYPERSENSITIVITY

The lasers used for the treatment of dentin hypersensitivity are divided into two groups:

- Low output power (low-level) lasers : He-Ne and Ga-Al-As lasers
- Middle output power lasers : Nd : YAG, Er : YAG and CO_2 lasers.

Laser effects are due to

- Effects of sealing of dentinal tubules
- Nerve analgesia or placebo effect

The sealing effect is lasting whereas nerve analgesia or placebo effects are not **(Figs 6.2A to D)**.

Fig. 6.2A: Cervical recession in premolar region causing dentinal hypersensitivity

Fig. 6.2B: Application of thin layer of stannous fluoride gel in the cervical area

Fig. 6.2C: Activation of stannous fluoride gel using laser under continuous movement of the handpiece

Fig. 6.2D: Repetition of the laser procedure 6 times for an overall exposure time of 30 secs per tooth

Lower Output Power Lasers

Initially it was used to support wound healing. Then as an anti-inflammatory tool. Later it was demonstrated that low output power laser therapy stimulates nerve cells in a clinical environment.

Helium-Neon Laser (He–Ne Laser)

- It was used for treatment of dentin hypersensitivity at an output power : 6 MW for 0.5-5 min.
- Irradiation modes are of 2 types : pulsed (5 Hz only) continuous wave (cw mode)
- Treatment effectiveness – 55 to 100%
- It does not affect peripheral Aδ or C-fiber nociceptors
- It does affect electric activity (Action potential) which in the healthy nerve increases by 33% following a single trans-cutaneous irradiation.
- It produces long-lasting effect, inducing an increase in the size of the nerve's action potential for more than 8 months after cessation of irradiation.
- With these lasers, there is no danger of causing skin burns or damaging cells.

Ga-Al-As Laser (Gallium, Aluminum, Arsenide)

- Use of Ga-Al-As laser at 830 nm with an output power of 20 to 60 mW in cw mode irradiated from 0.5 to 3 min had a treatment effectiveness which ranged from 30 to 100%.
- Use of Ga-Al-As laser at 900 nm at 2.4 mw, 1.2 km for 2.5 min had a treatment effectiveness ranging from 73.3 to 100%.

This type of low output power laser mediates an analgesic effect related to depressed nerve transmission. This effect is caused by blocking the depolarization of c – fiber afferents.

Ga Al As laser irradiation at a maximum power of 60 mW does not effect the enamel or dentin morphologically.

Middle Output Power Lasers

Nd : YAG :

Nd : YAG laser was used at 1,064 nm for the treatment of dentin hypersensitivity.

In a Study the output power was varied and ranged from 0.3 to 10 W, but 1 or 2 W output was most common.

Irradiation methods were dependent on the laser powers and varied from 0.3 W for 90s out of contact to 2 W for 0.5 s on black ink in contact mode. They even applied 10 W for 0.1 s. Treatment effectiveness ranged from 52 to 100%.

The use of black ink as an absorption enhancer for the effects of Nd : YAG laser irradiation prevents deep penetration of the laser beam through the enamel and dentin resulting in control of excessive effects in the pulp.

The mechanism is based on laser-induced occlusion or narrowing of dentinal tubules as well as direct nerve analgesia.

Laser energy at 1064 nm is transmitted through dentin, producing thermally mediated effects on microcirculation and pulpal analgesia via its nerve system.

Laser energy interferes with the sodium pump mechanism, changes the cell membrane permeability and temporarily alters the endings of the sensory axons.

It can also be regarded as a denaturation of the odontoblastic processes. If laser equipment is used at the correct specifications and the temperature increase to the pulp remains under 5.5°c, then, there will be no thermal damage to the healthy pulp tissue.

Diode laser and Ho : YAG

The diode laser application in combination with a fluoride gel could be advantageous due to continuous wave or chopped working mode of this device.

Irradiation with a diode laser (810 nm) at 0.2 or 0.5 W, 10 Hz, shows no closure in the cervical neck region.

Ho : YAG laser (2940 nm) treatment partial can lead to sealing of the dentinal tubules at a lower power setting (0.2 W) but not at a higher setting (0.5 W).

Er : YAG laser [Erbium-Doped : Yttrium, Aluminum and Garnet]

Desensitizing effects of an Er : YAG laser (2940 nm wavelength) are reported when irradiation occurred at an energy level of 80 mJ/pulse, 3 Hz with water irrigation in a defocused manner for 2 min/tooth by scanning in an overlapping pattern.

The energy setting used is lower than the ablation thresholds of dental hard tissues.

The high absorption of the Er : YAG laser emission wavelength in water may result in an evaporation of the dentinal fluid and the smear layer.

When two different Er : YAG lasers irradiated even at lowest possible power settings of 0.2 and 0.5 W, with and without prior application of a stannous fluoride gel resulted in the splitting off of dentinal hard tissue without sealing of dentinal tubules.

An Er : YAG laser has a water absorption characteristic ~15 times greater than that of CO_2 and even 20000 times greater than the Nd : YAG laser.

The Er : YAG laser shows the lowest limitation due to thermal side effects because of its thermomechanical ablation mechanism and high absorption of its wavelength by water.

CO_2 LASER

The CO_2 laser (10.6 μm) is the most frequently used laser for the treatment of dentin hypersensitivity.

The impact of this laser is based on a closure or stricture of the dentinal tubules.

There are two situations to utilize the CO_2 laser:

- Direct method: Exposed dentin is directly irradiated
- Indirect method: Irradiation is done in combination with a fluoride gel.

In indirect method, the stannous fluoride gel is first applied to the cleaned dental neck area and the actual laser irradiation is carried out through the gel layer.

For both the methods:

Out put powers of – 0.5 and 1 W

Mode – cw mode

Irradiation time – ranged from 0.5 to 5s and repeated 5-10 times.

Direct Method

Using CO_2 laser, at moderate energy densities, mainly sealing of dentinal tubules is achieved, as a reduction of permeability due to the occlusion or narrowing of dentinal tubules.

It also causes dentinal desiccation, yielding temporary clinical relief of dentinal hypersensitivity.

The sealing depth achieved by irradiation at 0.3 w for 0.1 s on dentinal tubules is usually measured to be 2-8 μm.

Treatment success of only 50% is reported.

Indirect Method

This procedure was developed based on the consideration to combine the advantages of laser, and fluoride therapy and thereby to achieve a durable treatment success.

It guarantees freedom from pain for a long period of time.

CLINICAL PROCEDURE

Initial Diagnosis and Evaluation

a. Initial examination to eliminate any possible reason that may mimic dentin hypersensitivity (e.g. fracture, cracked tooth or irreversible pulpitis).
b. Identification and if possible elimination of the etiology or process causing the hypersensitivity.
c. Inform patients about the treatment steps.
d. Professional oral prophylaxis is carried out.
e. Evaluation of pain on a scale ranging from 0 (free from pain) to 4 (unbearable pain) before treatment, by stimulating with air blast or alternative different stimuli (e.g. touch, cold, sweet, sour).
f. Rinsing and drying of the cervical area (Application of rubber dam).
g. Eye protection for every person in the room.
h. Application of a thin layer of $SnFl_2$ gel prior to irradiation **(Fig. 6.3A)**.
i. Operation mode of the CO_2 laser is continuous wave at an output power of 0.5 W.
j. 5 s of contact – free lasing of the hypersensitive dental neck region (around 5 mm) under continuous movement of the hand piece (at a distance of 1 cm – focal spot 1 mm^2).

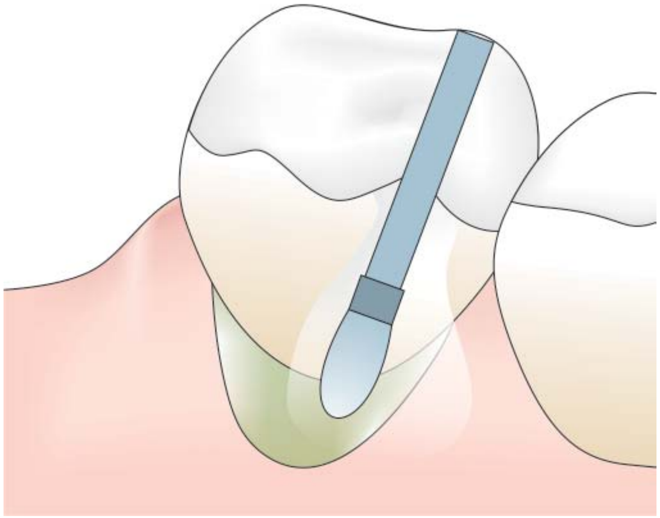


Fig. 6.3A: Application of $SnFl_2$ gel in the region of cervical recession

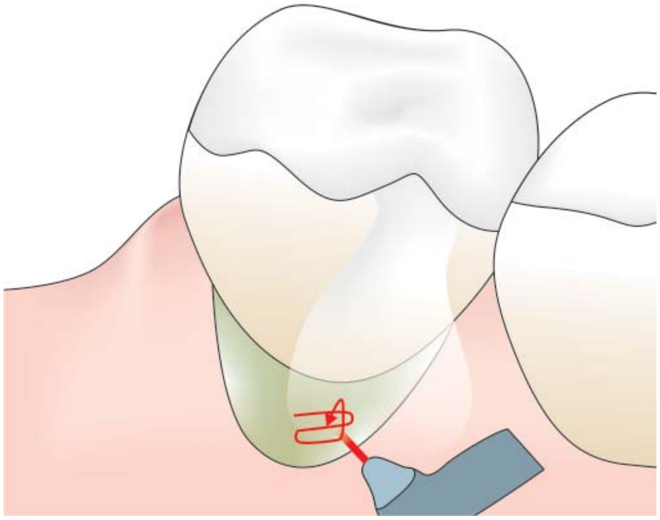


Fig. 6.3B: Activation of $SnFl_2$ gel using the laser in a continuous movement of the handpiece at a distance of 1 cm focal spot

k. 20 s break.
l. Six times repetition of the procedure for an overall exposure time of 30 s/region.
m. Evaluation of pain **(Fig. 6.3B)**.

II. Recall patient after 1 week and repeat the procedure.

III. Recall patient again after 2 weeks and repeat the procedure if necessary.

CHAPTER 7

LASER-ASSISTED COSMETIC DENTISTRY

- Introduction
- Causes of Tooth Discoloration
- Treatment Options
- Bleaching
- Clinical Procedure of Laser-assisted Teeth Whitening

INTRODUCTION

Tooth discoloration can be defined as changing of the color of the tooth in a way that it differs markedly from the adjacent teeth.

In most cases it is deviation to the darker hues. Genetic malformations and developmental disorders can affect several teeth of the dentition or may cause general discoloration. Average tooth color varies from white-yellow to yellow with gray, brown, green and pink shades. Tooth shape and tooth color are the main factors of influence in the esthetics of a dentition. Tooth discoloration interferes with normal esthetics.

Bleaching techniques have eliminated the need for invasive treatments and has became the treatment of choice. The indications for bleaching and the outcome of a treatment is highly dependent on the etiology of the discoloration.

CAUSES OF TOOTH DISCOLORATION

Tooth discolorations are classified as – Extrinsic and Intrinsic.

Extrinsic discolorations are caused by factors outside of a tooth.

Intrinsic discolorations are caused by internal factors.

Extrinsic Discolorations

It consists of a discolored superficial layer on the surface of the teeth. It occurs due to lifestyle habits and poor oral hygiene. They are removed primarily by conventional means such as prophylaxis, ultrasonic scaling, abrasive pastes or root planing.

Several Kinds of Extrinsic Discolorations

a. Plaque: It appears as white-yellow to green-brown
b. Tartar: Dental plaque calcifies to create tartar. It can appear both supra and subgingivally. The absorption of pigments found in various foods can change inherent yellow to white color of tartar to brown and black.
c. Deposit of tar: Smokers and tobacco chewers often show a brown to black deposit of tar especially on lingual surfaces.
d. Tea and wine: Both contain tannin, causing a brownish-black stain.
e. Chlorhexidine: Often used as disinfectant causes a brown staining.
f. Tinfluoride: Prolonged uses of Tinfluoride in treatment of hypersensitivity and caries prevention creates a deposit of tin sulfide and causes light- brown to gold-yellow staining.
g. Others include industrial deposits, nutrition, chromogenic bacteria, food supplements and medications.

Intrinsic Discolorations

Intrinsic discolorations originating from discolorations incorporated inside the teeth during the formation phase are called formative discolorations.

Discolorations originating after tooth development is complete, are called post-formative discolorations.

Discolorations in the Formative Phase

During dentinogenesis, pre and postnatal several discoloring substances can be incorporated into the dental structures.

Chemical Agents and Medications

1. Fluorosis

It is caused by the excessive intake of fluoride during the formation and calcification of enamel, approx from 3 months to 8 years of age.

- It can cause discolorations, surface alterations and defects. The type and severity caused by fluorosis depends on the genetic predisposition, concentration of the fluoride, duration of administration and stage of enamel development during uptake.

Types:

a. **Fluorosis simplex:** Shows sound enamel surface with a brown pigmentation caused by secondary infiltration of pigments from food.
b. **Opaque fluorosis:** It appears as dull, gray or white spot lesions.
c. **Pitting fluorosis:** Characterized by a dark pigmentation and enamel defects. Demineralization ranges from surface roughness to true hypoplasia and pitting.

2. Tetracycline staining

The discoloration may be caused either by incorporation or binding of tetracyclines to the tooth structure. It binds to the hydroxyapatite crystals of enamel and dentin.

Tetracyclines discoloration may be yellow, yellow–brown, brown, gray or blue. The intensity of staining varies and distribution is usually diffuse and in severe cases exhibit banding. Staining is usually bilateral and affects multiple teeth in both arches.

The severity of tooth discoloration depends upon four factors associated with tetracycline administration.

a. Age and time of administration.
b. Duration of administration: The severity of staining is directly proportional to duration of administration of medicine.
c. Dosage: It is directly proportional to severity of staining.
d. Type of tetracycline: Coloration has been co-related to specific type of tetracycline administered.
   - Chlortetracycline (Aureomycin): gray-brown stain
   - Dimethylchlortetracycline (Ledermycin): yellow stain
   - Oxytetracycline (Terramycin): yellow stain
   - Tetracycline (Achromycin): yellow stain
   - Doxycycline (Vibramycin): No staining.

Yellow tetracycline staining slowly darkens to brown or gray–brown when exposed to sunlight.

Therefore, anterior teeth often darken first than posterior teeth. Hypocalcified white areas of varying opacity, size and distribution may also be present.

Pre-eruption Trauma

Local injury or inflammation to the primary tooth can cause deficient enamel formation and white spots on the permanent tooth.

Systemic Diseases

Conditions like erythroblastosis fetalis, jaundice, hemolytic anemia and certain metabolic disorders can also cause staining of the teeth surfaces.

Congenital Disorders

Conditions such as amelogenesis imperfecta, dysplasia of dentin, dentinogenesis imperfecta, odontodysplasia of ghost teeth.

Granuloma Interna or Pink Spot

Internal resorption of dentin enlarges the pulp chamber, producing a pink discoloration of the tooth.

Iatrogenic Discoloration

Many materials used in an endodontic treatment may cause a tooth discoloration.

Caries

Caries is still one of the main causes of tooth discoloration.

Aging

The ongoing sclerotical process in the dentin and the retraction of the pulp chamber causes a darkening of the teeth with age.

TREATMENT OPTIONS

Proper diagnosis should be attempted before a course of treatment is promulgated.

Four methods of stain removal and improving esthetics are available.

1. **Polishing:** Hand Scalers, Ultrasonic scalers, Abrasive pastes and airflows allow the removal of superficial, extrinsic staining.
2. **Microabrasion:** If there is a superficial penetration of staining pigments, acid–abrasion techniques are efficient because of short-treatment time. It is limited to only most superficial discoloration due to its destructive nature.
3. **Bleaching:** It can be used to treat superficial staining and of nondestructive nature. They are the only technique available for deeper enamel stains and staining of the dentin.
4. **Restoration:** If the structural integrity of the teeth is compromised due to defects in enamel or dentin or both or if bleaching techniques fail, restoration through direct or indirect composite veneers, porcelain veneers or crowns is indicated.

BLEACHING

Bleaching is a chemical process for whitening teeth containing products with some form of hydrogen peroxide.

Best known commercial bleaching processes are peroxide, sodium per borate, chlorine and chloride. Peroxide bleaching requires the least time and is most commonly used. The strength can be designated by volume and by percentage of peroxide.

Bleaching processes are complex and work by oxidation process. It is a chemical process by which the organic materials are eventually converted into CO_2 and H_2O. Bleaching slowly transforms an organic substance into chemical intermediates that are lighter in color than the original. The oxidation-reduction reaction that takes place in the bleaching process is known as a redox reaction. Hydrogen peroxide is an oxidizing agent and has ability to produce free radicals which are very reactive.

Bleaching Mechanism of Teeth

In dental bleaching, Hydrogen peroxide diffuses through the organic matrix of the enamel and dentin. It increases the permeability of tooth structure, increasing the movement of Ions through the tooth. This occurs due to the low molecular weight of H_2O_2 and its ability to denature proteins. The extent of bleaching is determined by the amount of whitening compared to the amount of material loss.

During the initial bleaching process, highly pigmented carbon-ring compounds are opened and converted into chains that are lighter in color.

Existing carbon double-bond compounds, usually pigmented yellow, are converted into hydroxyl groups, alcohol-like which are mostly colorless.

As these processes continue the bleached material continually lightens.

The bleaching reaction will differ according to the type of discoloration involved and the physical and chemical environment present at the time of action, i.e. pH, temperature, co-catalysts, lightening and other conditions.

As bleaching proceeds, a point is reached at which only hydrophilic colorless structures exist. This is a *material's saturation point.*

Lightening then slows down and the bleaching process, if allowed to continue, begins to breakdown the carbon backbones of proteins and other carbon-containing materials.

Compounds with hydroxy groups, usually colorless, are split, breaking the material into yet smaller constituents. Loss of enamel becomes rapid, with the remaining material being quickly converted into carbon dioxide and water.

These reactions are common to all proteins, including those of enamel and dentin.

The saturation point is located in the middle of the process.

The ultimate result of bleaching processes is, like other oxidation processes, breakdown and loss of tooth enamel.

Optimal bleaching achieves maximum whitening, while over bleaching degrades tooth enamel without further whitening. Therefore tooth bleaching must be stopped at or before the saturation point **(Flow chart 7.1)**.

The saturation point, at which the optimal bleaching has occured, is located in the middle of the diagram.

Conventional Bleaching

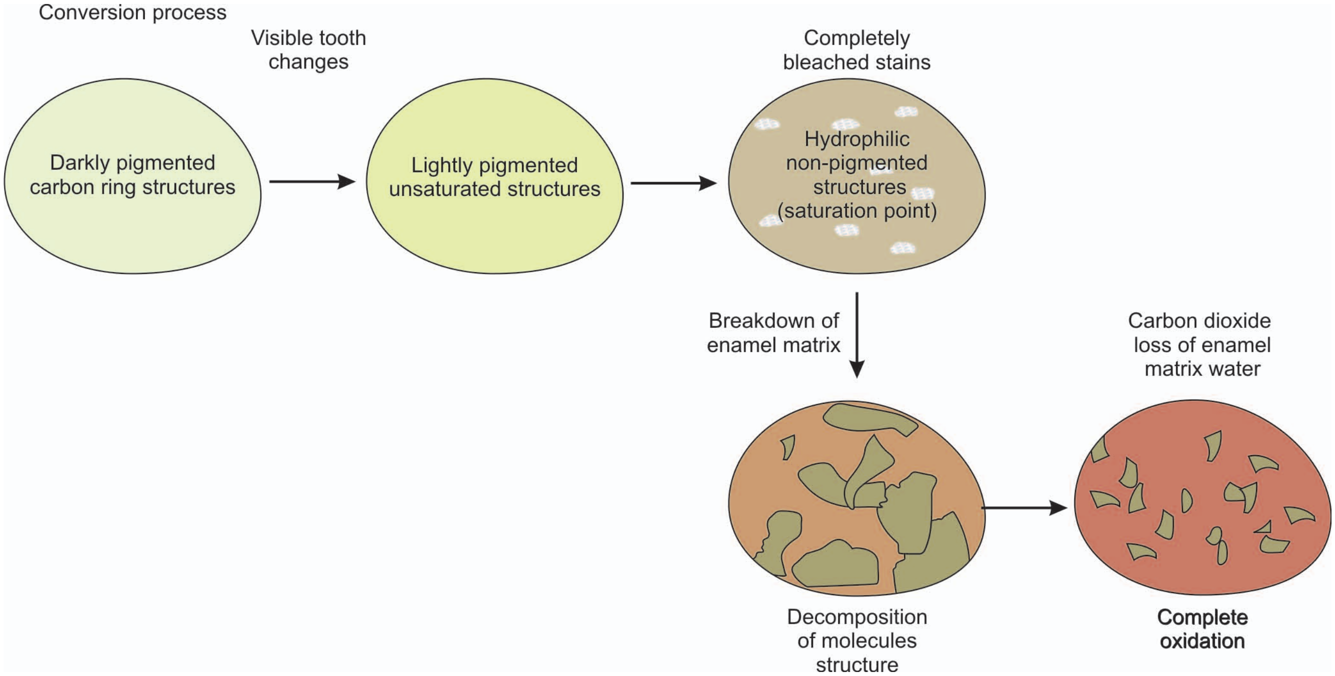
Home Bleaching

The active Hydrogen peroxide concentration should be between 30% and 35% resulting in the most effective bleaching reaction.

Gels are commonly used rather than aqueous solutions. By mixing powder and liquid prior to application, the hydrogen peroxide concentration will decrease by 25%. Gels are more effective in achieving a sealed environment promoting the efficiency of the whitening reaction. Teeth should be thoroughly cleaned, as the remaining organic material will interact with the bleaching agent resulting in inadequate reaction. Overall exposure time of the teeth to the bleaching agent should not exceed 30 minutes, as prolonged exposure time may affect the enamel surface. The bleaching gel should have a basic pH in the range of 9.8 to 10.5.

The long lasting and safe tooth whitening effect depends on the pH of the gel applied, the rate of the chemical reaction, the radicals produce and the energy source used. Home bleaching procedures never make use of additional applied energy to increase the release of the active bleaching radicals. They use lower concentration of the hydrogen peroxide but with a prolonged exposure time. Fitted trays containing the bleaching gel remain in contact with the teeth to be bleached for a period of time ranging from several hours through to overnight. Treatment is usually performed during the night, hence it is also defined as Night guard

Flow chart 7.1: Oxidation process associated with Bleaching process



vital bleaching (NGVB). Bleaching gel may contain hydrogen peroxide in concentrations of 2-6% or carbamide peroxide in concentrations of 10-15%. The carbamide peroxide dissolves in H_2O_2 and urea during the bleaching action.

↓ ↓ ↓

H_2+O $H+H_2O$ HN_3+CO_2

Chemical breakdown of carbamide peroxide

10-15% carbamide peroxide produces 3-5% of hydrogen peroxide and 7-10% urea. Carbopol added to increase the viscosity of the gel and releasing of the peroxide. Phosphoric acid or citric acid is added to increase the shelf-life gel and stability of hydrogen peroxide.

Disadvantages

Prolonged use of home bleaching products will cause dentin and enamel surface alterations, etching and demineralization. High concentrations of acids can cause carious lesions especially in the cervical region due to high degree of demineralization. It should always be performed under professional supervision because of several possible risks, e.g. carcinogenicity of the hydrogen peroxide in combination with smoking during treatment. It can only effectively treat mild discolorations, mostly in the yellow range.

In-office Bleaching

Different kinds of energy sources are used to increase the rate of the chemical release of bleaching radicals.

The use of direct heating has been replaced by other energy sources such as plasma-arc devices, halogen lamps, InGaN LEDs or light emitting diodes. Lamps emitting long wavelengths, i.e. visual spectrum or IR spectrum have lower energy photons with a high thermal character. Shorter wavelengths, such as Argon laser or KTP laser have higher energy photons with less direct thermal characteristics **(Figs 7.1A and B)**.

In-office vital tooth bleaching procedure, the use of light did not result in perceptibly brighter teeth. It appeared that light and heat do not increase tooth lightening and therefore are not necessary for the procedure, whereas the contact time and concentration of Hydrogen peroxide were more critical factors in producing more effective results. The specific features of the light energy produced by a laser appears to add beneficial effects to the rate of the chemical bleaching reactions. It has the unique property of being absorbed by chromophores.

Emulsions can be added to the bleaching gel, capable of absorbing the laser energy and inducing and promoting a fast, effective and safe redox-reaction. Different lasers produce different wavelengths, hence

Fig. 7.1A: Example of a KTP laser unit with handpiece

Fig. 7.1B: Diode laser handpiece used for teeth whitening

not all lasers are suitable for bleaching. Wavelengths absorbed by, scattered in or transmitted through the tooth structure cannot be used for bleaching as they will damage enamel and dentin or may even cause adverse effects in the vital pulp structures leading to irreversible damage and even necrosis of the tooth.

KTP, Argon and diode lasers are commonly used for in-office bleaching treatments. The energy of a KTP induces a photochemical activation which providers a higher intrinsic overall radical yield than thermal activation. The KTP laser gives more moderate and gradual temperature changes at the level of the dental pulp and is more efficient at heating the surface gel. The bleaching gel also retains its elevated temperature for an extended period.

With all laser systems, intra-pulpal thermal changes are related proportionately to both laser power and irradiance and inversely to tooth thickness. If gel is omitted there will be greater pulpal and thermal changes. The absorbing properties of the gel play an important role in influencing both surface and intra-pulpal thermal effects **(Fig. 7.2).**

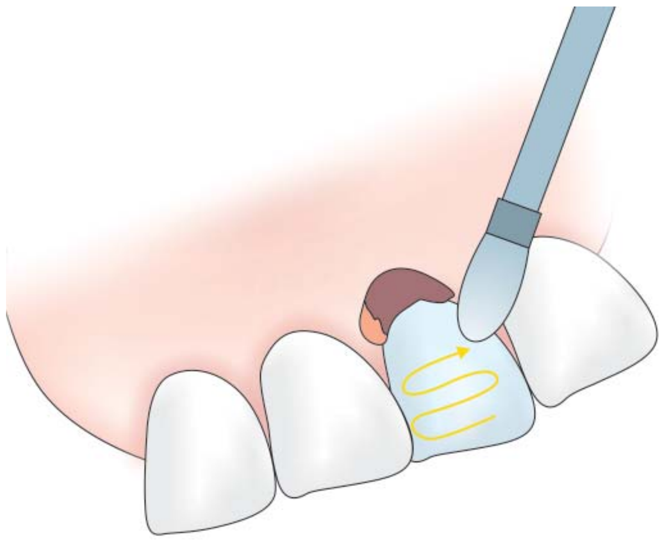


Fig. 7.2: Schematic representation of laser-assisted teeth whitening showing the direction of the movement of the laser handpiece

The KTP laser can be used with higher energy densities, decreasing the time needed for bleaching teeth with improved efficiency. Whitening effect of photochemical laser is greater than that of diode laser. KTP laser is also capable of inducing a decomposition reaction of the staining agent. The use of laser source emitting energy minimizes the risk of damaging the tooth structures such as enamel, dentin and the vital pulp system. The use of specific wavelengths of laser energy together with an appropriate chemical agent will enhance both efficiency and safety of in-office bleaching treatments.

When passing through a tissue or a material, the attenuation of a laser beam increases exponentially with the transmission depth. Temperature changes inside the pulp, depend upon the degree of attenuation of the laser beam, the initial intensity of the laser beam and the time of irradiation.

Temperature measurements were made at intervals of 5 secs using two different power settings 1W and 2W and overall irradiation time of 60 secs. Titanium dioxide was used as an absorption agent in a ratio of 1:1 by percentage of weight.

Average output power of 2 watt and bleaching gel the temperature increase in the pulp is about 8°C. By adding TiO_2, temperature increase can be reduced to about 2.5°C.

With an output power of 1 watt and bleaching gel temperature increase is about 3°C.

Laser Assisted Nonvital Tooth Bleaching

Non-vital, internal bleaching of a tooth always holds a risk for internal resorption of the root. Special precautions and effective isolation of the dentin tubuli, reaching the area of the tooth surface must be ensured **(Figs 7.3A to G)**.

Fig. 7.3A: Preoperative photograph showing non-vital teeth in relation to 21 and 22

Fig. 7.3B: Palatal view of the non-vital teeth

Fig. 7.3C: Application of bleaching agent following that of gingival guard

Fig. 7.3D: Laser-assisted bleaching of the non-vital teeth

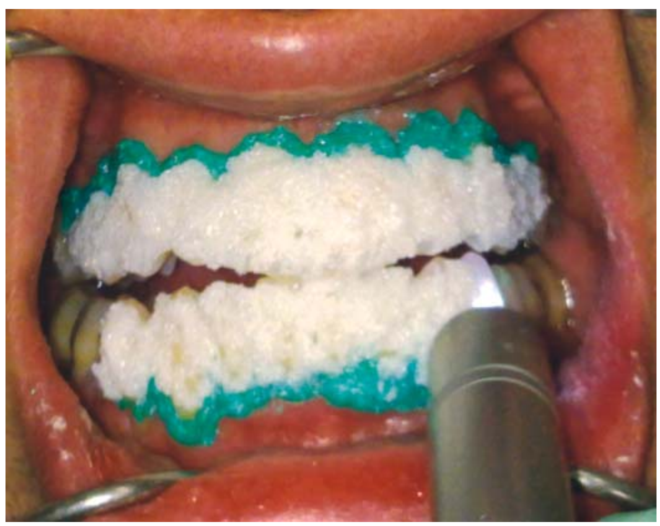


Fig. 7.3E: Followed by full mouth laser-assisted bleaching

Fig. 7.3F: Application of desensitizing gel post-bleaching

Fig. 7.3G: Postoperative view

For each application, the gel must remain on the tooth for 10 minutes. Laser should be applied to the labial as well as the palatal/lingual side. Two to three 30-sec cycles of laser should be done in the 10 minutes duration. Treatment should be stopped when the affected tooth is still a shade darker than the adjacent tooth as the bleaching affect continues within the porous dentin for several hours post-treatment.

Variations in the gel ratio

Changes in the percentage by weight of TiO_2, showed a difference in pulpal temperature increase. After 30 secs of irradiation with power setting of 1W, thicker the gel, more difficult it is to handle and apply it to the tooth surfaces. Pulpal temperature increases at different exposure times and with different gel ratios.

By adding TiO_2 to the bleaching gel in a ratio of 1:1, the diode laser may be used as a safe tool in vital tooth bleaching, as the pulpal temperature increase can be reduced.

Table 7.1

Contraindication for laser assisted teeth whitening
Enamel fractures
Hypersensitive dental necks
Leaking fillings
Mandibular joint disorders
Periodontal problems
Pregnancy

CLINICAL PROCEDURE OF LASER-ASSISTED TEETH WHITENING

Diagnosis and Treatment Planning

Diagnosis of the etiology of tooth discoloration is the most important determinant for the success of tooth bleaching. The next most important predictive factor is the condition of teeth and oral cavity. The individual patient's desires and expectations must be carefully assessed **(Fig. 7.4A)**.

Fig. 7.4A: Preoperative view

A visual examination should determine the following:

- The cause of the dental staining
- The extent and depth of discoloration
- Whether a bleaching treatment is indicated.

It is important to perform thorough oral prophylaxis to see the extent of deep stains and to prepare the teeth for the actual bleaching procedure. The patient should be informed of the expected outcome of the bleaching treatment and its possible side effects. A complete clinical and radiographic examination of the oral cavity should be done, including vitality and sensitivity tests to detect soundness of the teeth and/or restorations.

Oral Prophylaxis and Application of Gingival Barrier

Perform thorough scaling of the teeth, plaque and debris has to be removed in order to obtain optimal results. Use airflow or pumice and water. Polishing pastes may not be used because they contain oils, which inhibit laser energy and the redox reaction. Position a check-retractor and cotton rolls into the patient's mouth. Give the patient safety goggles to wear. Dry the teeth and gums thoroughly using compressed air. Apply the gingival protection material and polymerize **(Fig. 7.4B)**.

Follow the gingival margins and squirt into the sulcus, cover the cervix and about 1 mm of the teeth. Also cover the exposed dentin or spots. Accidental spots have to be removed because inhibition of the whitening reaction will occur wherever the blocking material is present.

Preparation of the gel

Shake the powder well before use. Mix about 5 ml of peroxide with the powder. Mix powder and liquid well, close the lid and let rest for 5 minutes to allow the pH to rise. After each application, close the lid and seal well. The gel has a pH value of ~10 after laser irradiation. The viscosity of the gel can be adapted by changing the volume of peroxide.

Application of the gel

Apply the gel on the teeth with a brush or spatula. Always start with the upper front teeth as they are bigger in size and have thick layer of enamel. Apply the gel on the teeth as follows in first application **(Fig. 7.4C)**.

11, then 21, 12-22, 13-23, 14-24, 15-25

followed by

41-31, 42-32, 43-33, 44-34, 45-35

Irradiate each tooth for 30 seconds in the same sequence as gel application. Use an average power setting of about 1 watt. Energy densities on the surface of the gel can be decreased, by increasing the distance of fiber tip from the surface. If unfavorable or unacceptable sensitivity occurs, decrease energy densities or reduce the average power setting. Aspirate the gel, rinse thoroughly and dry gently.

If accidental contact of the gel occurs with soft tissue or skin, immediately apply a thick layer of Vit.E gel. This is a strong anti-oxidants which stops the irritating and burning sensation almost immediately **(Fig. 7.4D)**.

Fig. 7.4B: Application of the gingival barrier

Fig. 7.4C: Application of the bleaching gel

Fig. 7.4D: Laser activation of the bleaching gel

Fig. 7.4E: Postoperative view

Apply new gel in slightly different mode in second application.

Start in the upper arch with tooth 21 then 11, 22 then 12, ...

In the lower arch with 31-41, 32-42, ...

Irradiate each tooth again for 30 seconds in the same sequence as applying the gel and with the same power setting of the laser. Rinse thoroughly and dry gently. Check the color of the teeth and decide whether to continue or not. If so, restart the procedure in the same sequence as with the first application.

Selective application of several teeth is possible, as well as selective application to restricted areas on a single tooth or teeth, if these show more intense discolorations. Always respect the 30 secs of irradiation time per tooth and 10 minutes overall interaction time before sucking off the gel and rinsing. A maximum of four 10 minutes passes can be performed in one treatment session.

Remove the gingival protection; apply fluoride gel liberally with a brush or spatula. Irradiate every tooth for 15 seconds **(Fig. 7.4E)**.

The Fluoride and laser energy provides a profound resistance for the enamel and dentin to future acid attacks. Remove check-retractor, cotton dry-field system and glasses. Discuss the result of the treatment with the patient. Give instructions for the use of the maintenance gel. Make an appointment for a control session after 2 weeks and one after 6 months.

Laser-assisted Crown Lengthening Procedure

Crown lengthening procedures are indicated within the esthetic zone require special consideration to achieve predictable esthetic results. Whether they are performed for the purpose of exposing sound tooth structure, or to enhance the appearance of definitive restorations, these procedures must be planned to satisfy biologic requirements, while simultaneously avoiding deleterious esthetic effect.

Indications of crown lengthening procedure:

1. Caries at gingival margins.
2. Cuspal fracture extending apical to the gingival margin.
3. Endodontic perforations near alveolar crest.
4. Insufficient clinical crown length.
5. Difficulty in placement of finish line coronal to the biologic width.
6. Need to develop a ferrule.
7. Unesthetic gingival architecture.
8. Cosmetic enhancement.

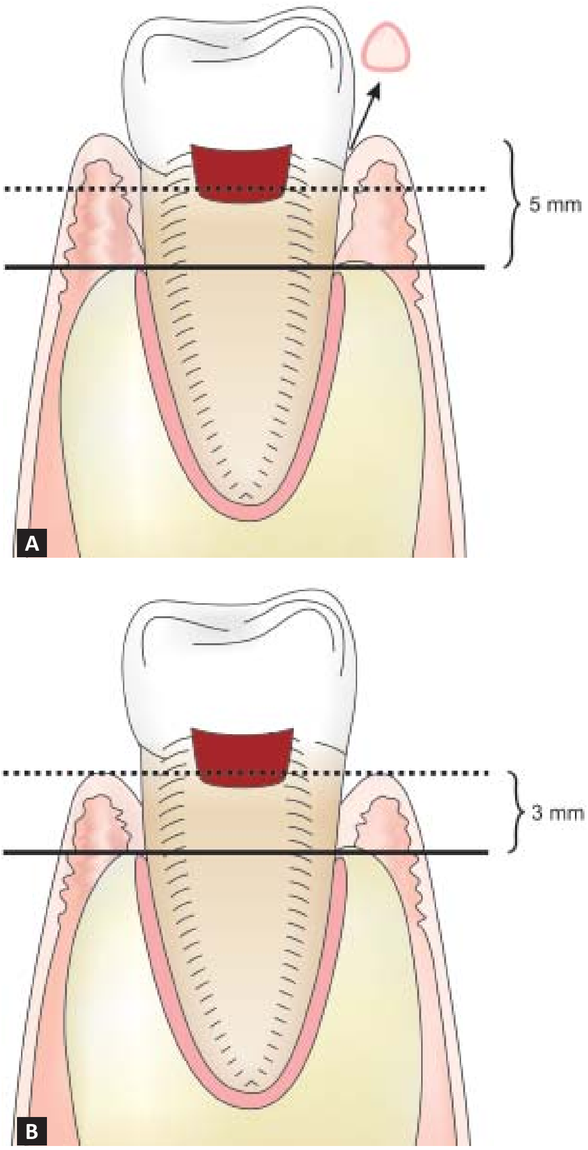
Various techniques of crown lengthening:

- Surgical procedure
- Electrosurgery
- Orthodontic extrusion
- LASER

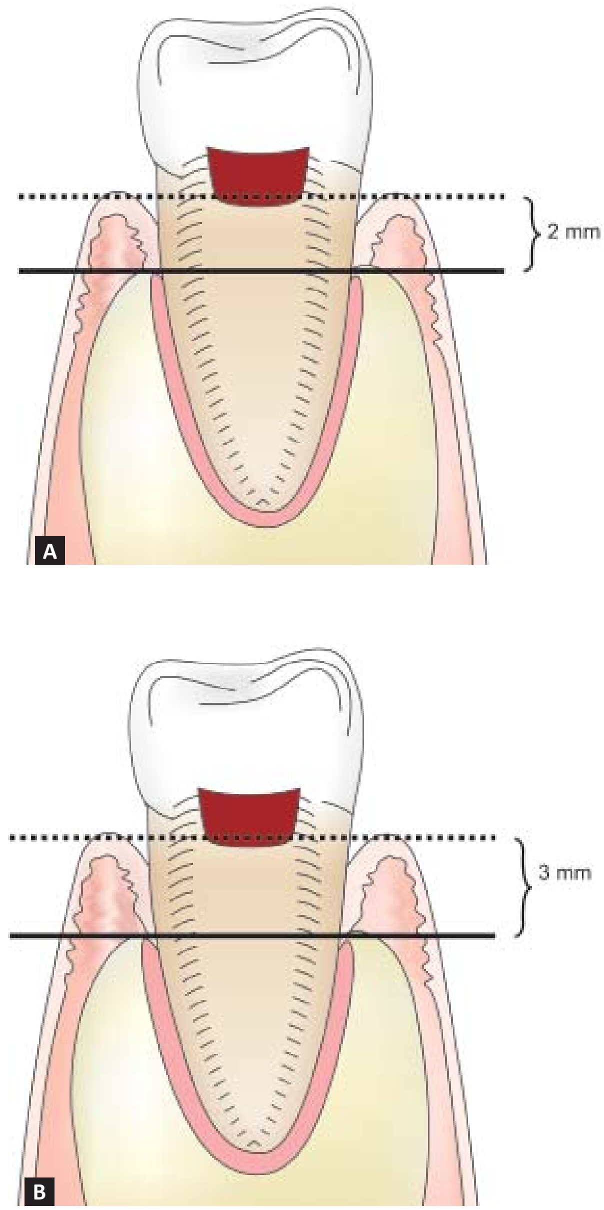
Surgical crown-lengthening procedures are performed to provide retention form to allow for proper tooth preparation, impression procedures, and placement of restorative margin and to adjust gingival levels for esthetics. It is important that crown-lengthening surgery is done in such a manner that the biologic width is preserved. The biologic width is defined as the physiologic dimension of the junctional epithelium and connective tissue attachment. This measurement has been found to be relatively constant at approximately 2 mm (±30%). The healthy gingival sulcus has shown an average depth of 0.69 mm **(Figs 7.5A and B)**.

Surgical crown lengthening may include the removal of soft tissue or both soft tissue and alveolar bone. Reduction of soft tissue alone is indicated if there is adequate attached gingiva and more than 3 mm of tissue coronal to the bone crest. This may be accomplished by either gingivectomy or flap technique. Inadequate attached gingiva and less than 3 mm of soft tissue require a flap procedure and bone recontouring **(Figs 7.6A and B)**.

Indications:
- Subgingival caries or fracture
- Inadequate clinical crown length for retention
- Unequal or unesthetic gingival heights.



Figs 7.5A and B: Crown lengthening procedure on gingiva with adequate biologic width, i.e. in cases with more than 3 mm of soft tissue



Figs 7.6A and B: Crown lengthening procedure through osseous recontouring on gingiva with inadequate biologic width, i.e. in cases with less than 3mm of soft tissue

Fig. 7.7A: Preoperative view

Fig. 7.7B: Tissue markings showing the level of gingiva to be excised

Fig. 7.7C: Gingival margins immediately after laser assisted surgery. The coagulation negates the need for sutures and periodontal pack

Fig. 7.7D: Gingival margins 3 days postsurgery

Contraindications:

- Surgery would create an unesthetic outcome.
- Deep caries or fracture would require excessive bone removal on contiguous teeth.
- The tooth is a poor restorative risk **(Figs 7.7A to D)**.

Laser-assisted Crown Lengthening Clinical Procedure

- Intraoral periapical radiographs are taken and bone sounding is done in lower anterior region using periodontal probe.
- Gingival width is marked with tissue marking pencil at the estimated and desired position from canine to canine taking into consideration the maintenance of the biological width.
- The gingival tissue above the marking is cut with the help of laser tip without any anesthesia. The procedure parameters are set as power settings at 1.25W, 7% water, 11% air. The procedure is generally bloodless and painless.

Laser-assisted Gingival Depigmentation Procedure

The smile is determined not only by the shape, the orientation and the color of the dentition but also by the health and appearance of the gingival tissues. Melanin hyperpigmentation or darkened gums, usually does not present a medical problem, but can be esthetically very unpleasant in extreme cases leading to psychological issues of low self-esteem. This condition presents as a brown coloration in the tissue, particularly concentrated near the gingival margin.

Melanin, carotene and hemoglobin are the most common natural pigments contributing to the normal color of the gums. Gingival depigmentation has been carried out successfully several times in the past using nonsurgical and surgical procedures. Recently, laser ablation has been recognized as a most effective, pleasant and reliable technique.

The lasers are extremely easy to use with no bleeding. Lasers cut the tissue effortlessly and it is easy to maintain the tissue profile. Immediately postoperative, the gums generally appears healthy and reddish pink with no sign of charring or any thermal damage to the tissues evident. Healing and initial epithelization occurs after 24 hours.

In the conventional procedure an epithelial excision or partial/split thickness flap is planned. The pigmented gingival epithelium is removed using the scalpel. The epithelium from the tip of inter-dental papilla up to the mucogingival junction is generally included in the excision. Hemostasis is achieved with sterile gauze and direct pressure and the surgical wound will have to be protected by a periodontal dressing for the immediate two-week postoperative period.

By contrast, using the laser, there was no requirement for injected anesthetic, no bleeding, no requirement for a dressing, reduced chance of infection because the laser produces a sterile field, less swelling and pain and much more rapid healing.

Lasers have truly made soft tissue surgery procedures easy, uncomplicated and comfortable both for the Dentist and the Patient.

CONCLUSION

All the other crown lengthening procedures has certain disadvantages as in surgical approach healing time is longer, post-healing gingival margin position is unpredictable, and patient compliance is poor as it needs use of anesthesia and scalpel. In electrosurgery, the heat liberated has a deleterious effect on pulp and bone leading to pulpal death or bone necrosis. Orthodontic extrusion leads to vertical bone defect adjacent to extruded tooth and it also needs patient compliance. On other hand esthetic crown lengthening is a technically demanding endeavor that requires gingival incisions exhibiting higher degree of precision, than what may be achieved with routine methods.

Laser offers unparalleled precision and operator control and may be beneficial for finely tracing incision lines and sculpting the desired gingival margin outline, while also achieving excellent hemostasis and postsurgical healing, increasing postsurgical gingival margin predictability.

CHAPTER

8

Laser Application in Pediatric Dentistry

- Direct Pulp Capping
- Procedures
- Pulpotomy
- Soft Tissue Lasers Applications in Pediatric Dentistry
- Application of Lasers on Infantile Oral Soft Tissue Lesions

DIRECT PULP CAPPING

It is considered a valid treatment method in today's endodontics because capping can preserve tooth vitality in an exposed cavity. It is a procedure in which medicaments are placed over the accidental or traumatic exposure of healthy or reversibly damaged pulps in order to preserve the tooth vitality.

The most commonly used capping material is calcium hydroxide. The healing of the pulp exposures depends on the capacity of the capping material to prevent micro-leakage. Younger the patient is better progress for dentin bridging and pulpal healing **(Tables 8.1 and 8.2)**.

Table 8.1

Indications of direct pulp capping
– Tooth fractures with exposure of the pulp chamber
– Small iatrogenic opening of the pulp chamber during preparations
– Pulp exposure after caries removal in immature permanent teeth

Table 8.2

Contraindication of direct pulp capping
– Pulp exposure as a result of caries penetration into the pulp chambers
– Pulpitic teeth
– Chronic or sub-acute pulpitis
– Large fractures or iatrogenic opening

Prerequisites for Direct Pulp Capping

- Absence of chronic or sub-acute forms of pulpitis - no inflammatory alteration of the pulp (absence of carious dentin at the site of the pulpal wound)
- Pulpal exposure <1 mm^2
- Hemostasis.

PROCEDURES (TABLES 8.3 AND 8.4)

Conventional Pulp Capping

Calcium Hydroxide

Material of choice

Table 8.3

Conventional pulp capping
• Calcium hydroxide
• Total etch technique
• Mineral trioxide aggregate
• Bioactive molecules
• Antibiotics
• Corticosteroids

Table 8.4

Laser assisted pulp capping
• Nd : YAG
• Er: YAG
• CO_2 laser

Mechanism

Due to superficial necrosis resulting from high alkaline pH of the capping material and subsequent formation of fiber-rich scar tissue, normal pulp cells are transformed into secondary odontoblasts and tertiary dentin is formed.

Conventional treatment regimes are founded on a bacteria-free, tight capping of the pulp wound and a provisional filling with a minimum of microleakage.

Procedure

Hemostasis:

- Wash the area with sterile saline followed by application of cotton pellets soaked with hydrogen peroxide or 5% sodium hypochlorite
- Addition of hemostatic agent is sometimes useful.

Disinfectant:

- Cavity floor should be treated with a suitable disinfectant.

Dressing:

- After air drying, the calcium hydroxide is applied to the site of exposure directly in contact with the pulpal tissue
- Better the contact of calcium hydroxide with the pulpal wound, better the healing.

Temporary filling material:
Either resin-modified glass ionomer cements or immediate restorative materials.

Final restoration can be made after 3 months if no symptoms are evident **(Table 8.5)**.

Table 8.5

Prognosis
Depending on:
• Diameter of exposed pulp
• Location of capping
• Patient's age
• Durability of the restoration
• Bacterial invasion
• Success rate: 44% - 95%

Laser-assisted Pulp Capping

CO_2 Laser

It is a valuable surgical tool. This wavelength offers innovate options in the field of conservative dentistry. The most important effects of CO_2 laser irradiation seems to be sterilization and scar formation in the irradiated area due to thermal effects, which may help to preserve the pulp from bacterial invasion. There is reduced swelling, edema and pain. It minimizes the formation of a hematoma between the pulp tissue and hydroxide dressing, allowing a tight contact of the dressing to the exposed pulp. It emits at a wavelength of $\lambda = 10.6\ \mu m$, which is readily absorbed in the abundant water of soft tissues. Tissue penetration of the laser beam is minimal and its effects remain superficial and limited to the impacted area. Since irradiation of the exposed pulp is undertaken in non-contact mode, iatrogenic bacterial contamination of the treated site is minimal. It can be operated in a superpulsed mode, thereby reducing the thermal stress of the surrounding tissues and collateral damage to dental hard tissues **(Fig. 8.1)**.

Fig. 8.1: Example of CO_2 surgical laser

Procedure:

- Pulp capping with a CO_2 laser represents an easy, fast and safe method to achieve homeostasis, disinfection and coagulation of exposed pulp areas.
- Laser beam is applied in a contact–free mode utilizing a He-Ne laser to facilitate targeting.
- Irradiation commences after the exposure of vital pulp.
- The area is repeatedly irradiated at the power setting of 1 W for 0.1 s with a 1 s interval until homeostasis occurs and the aperture is completely sealed.
- Due to high absorption in water and its superficial mode of action on small blood vessels and capillaries hemostasis can be achieved in 2-3 irradiation cycles.
- The lased pulps are dressed with calcium hydroxide and cavity is filled with glass ionomer cement.
- Final restoration is recommended after 6 months in order to observe the healing process and the course of vitality. Recall examinations should be undertaken monthly for 1 year after treatment.

Vitality Tests following Laser-assisted Pulp Capping

Conventional cold test can be used for vitality assessment.

Laser doppler flowmetry can be utilized for direct measurement of the pulpal flow.

Typical perfusion curves synchronous with heart beat and vasomotion can be obtained, which alters assessment of the vitality of a tooth.

PULPOTOMY

Introduction

- It is defined as the surgical removal of the coronal pulp in an attempt to maintain the health of the remaining pulp.

In 1904, Sweet introduced the treatment of cariously exposed vital pulp with formocresol solution. Due to its good results, the 1:5 dilution of Buckley's formocresol became very popular way to treat the primary teeth with exposed coronal pulpitis.

Laser-assisted Pulpotomy

- The excavation of the carious dentin and removal of the pulp chamber has to be done with a high-speed handpiece and water spray.
- The pulp amputation has to be completed with a slow-speed round bur.
- If a child is treated under LA, a rubber dam should be used.
- Following the amputation, the root pulp stumps are lased at the canal orifice **(Fig. 8.2)**.

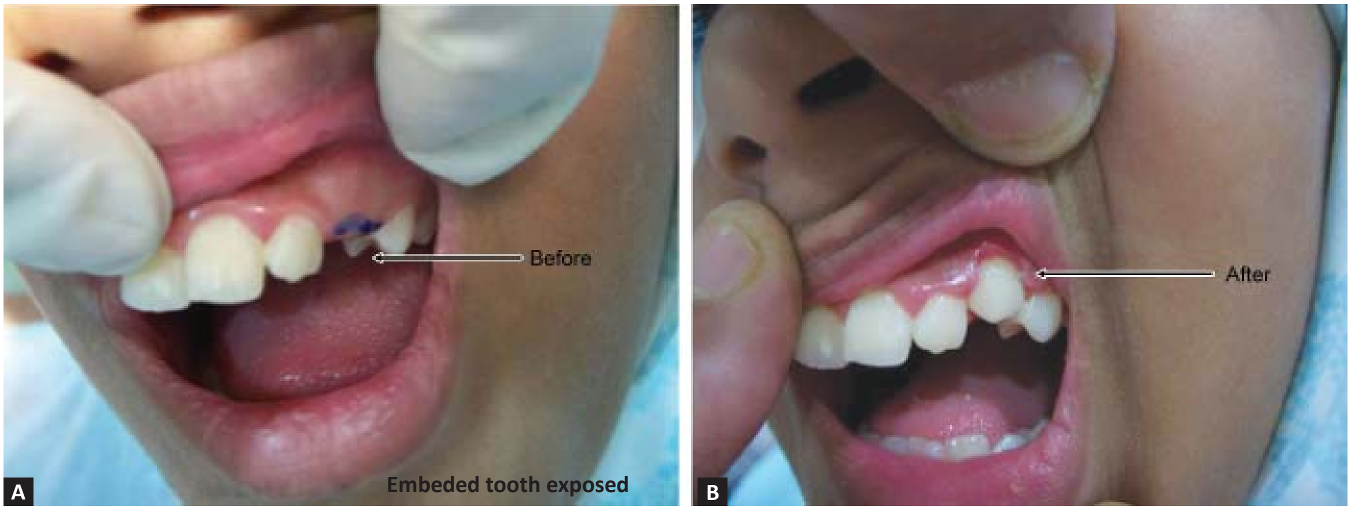
Fig. 8.2: Example of Er:YAG laser unit

- This procedure should be repeated for 5 to 10 s until a charred layer is present over the root pulp stumps and there is no evidence of recurrent bleeding.
- The hemorrhagic effect can be achieved by a laser power output of 3 W in a super pulsed mode defocused.
- After cleaning the cavity with hydrogen peroxide, the treated pulp stumps have to be dressed with zinc-oxide eugenol and zinc phosphate cement.
- The tooth should be restored with a stainless steel crown.
- For pulpotomy in primary molars, it is important to use the shortest tip for the laser handpiece for easy handling in the child's mouth.
- The ceramic tip is more efficient for homeostasis than a smaller metal tip in which it takes longer time and more movement of handpiece to stop the bleeding and pulp tissue.

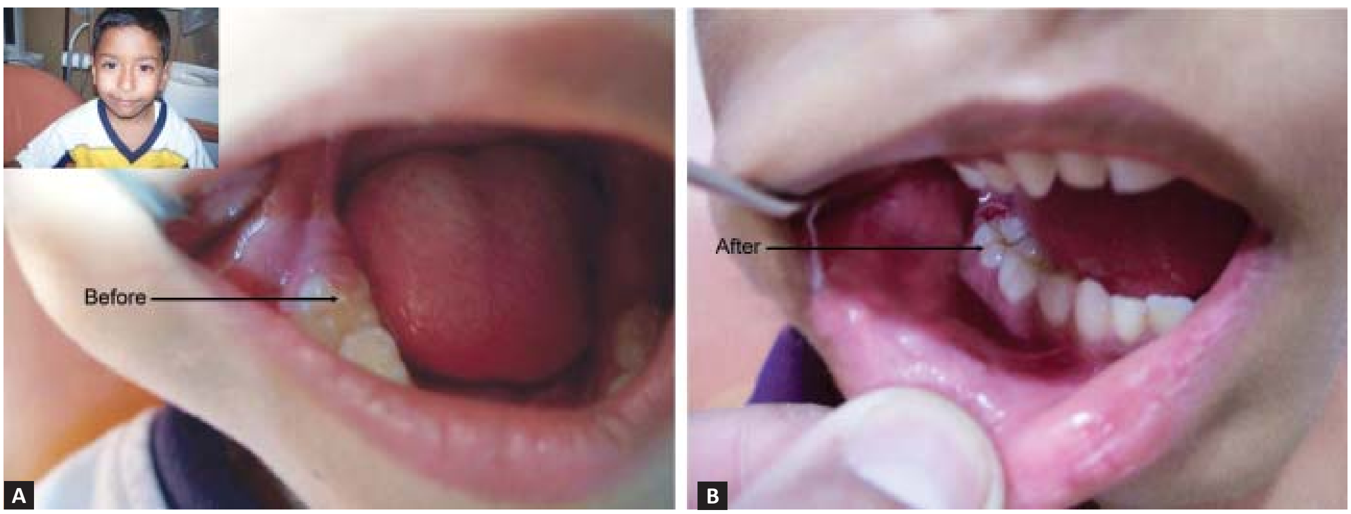
In some cases, it is useful to remove some of the excessive gingiva around the tooth for a better placement of pediatric steel crown. In such cases, **CO_2 laser can be used with increased power output of 4 W and the mode has to be changed from superpulsed into the continuous modes.** A metal instrument should be placed between the enamel and the laser beam in order to protect the enamel during the removal of the gingival. Sufficient suction is important to avoid the inhalation of the removed vaporized material. The same laser parameter can be used for the coronal pulp amputation instead of slow-speed round bur. But, once the laser comes closer to the channel orifice after removal of coronal pulp, the power output has to be reduced again to 1 W and continuous wave made to be changed back into superpulsed mode.

SOFT TISSUE LASERS APPLICATIONS IN PEDIATRIC DENTISTRY

- Excision of gingival overgrowth/tissue growth associated with unerupted teeth
- Excision of hyperplastic gingival tissue to aid eruption of incisors and cuspids
- Labial and lingual frenectomies
- Laser "bandaids" for aphthous ulcers
- Direct pulp capping
- Pulpotomies
- Excision of a fibroma
- Operculectomies
- Gingivectomies
- Gingivoplasties
- Treatment of oral lichen planus (Figs 8.3A and B).



Figs 8.3A and B: Exposure of un-erupted tooth



Figs 8.4A and B: Operculectomy in relation to the first permanent molar on a 6-year-old pediatric patient

APPLICATION OF LASERS ON INFANTILE ORAL SOFT TISSUE LESIONS

Oral soft tissue lesions in infants and very young children provide an unparalleled challenge for the pediatric dentist. The young and naive oral mucosa needs to be treated with a lot of finesse. The naturally anxious behavior of the child may not cooperate well for the administration of the local anesthetic injection as well the use of a conventional dreaded scalpel. Most importantly, tissue lesions around a natal/neonatal tooth have to be carefully evaluated before planning any kind of an invasive intervention.

This is because, the vitamin K dependent clotting elements take several weeks to form and any kind of a surgical intervention before they achieve their full functional abilities could indeed run the risk of extensive postoperative bleeding. Many cases need extensive suturing and postoperative antibiotics as well as analgesics. Amidst this background if we contemplate upon the use of laser it would indeed end up being termed a boon.

The problems associated with postoperative bleeding are almost non-existent and so are the needs for a local anesthetic injection, suturing or postoperative antibiotics and analgesics. Added to this is the gift of immaculate scar-free healing with zero postoperative complications **(Figs 8.4A and B)**.

CHAPTER 9

Laser in Endodontics

- Introduction
- Root Canal Sterilization
- Description of the Different Wavelengths
- Root Canal Preparation
- Apical Sealing
- Safety in Laser Treatment
- Indications
- Practical Procedure

INTRODUCTION

Different lasers are being used in root canal preparation, cleaning of the canal walls, disinfection of canals and surrounding dentinal tubules, removal of the smear layer and sealing of tubules. Laser is effective in eliminating bacterial infection and preventing its recurrence. When used in conjuction with traditional techniques, it will significantly enhance the long-term success of endodontic treatment.

Endodontic Problems

Endodontic procedures carried out by conventional methods may not be successful in spite of utmost care. Bacteria and their toxins that spread from the root canal and contaminate the apical region cause inflammation, infection and bone resorption. The therapeutic goal of each root canal treatment has to be decontamination of the root canal and accessory canals, along with dentinal tubules. A sterile, bacteria-free environment has to be created both in the tooth and at the apex, including the periodontal membrane and the surrounding apical bone in order to ensure that the osteoblasts in the apical area be able to complete the healing process.

There are two factors that complicate achieving sterility in the tooth:

- The anatomical root configuration
- The special characteristics of the resident bacterial flora.

For successful endodontic treatment all bacteria within the complex root canal system have to be completely eliminated.

Despite mechanical removal, irrigation and disinfection of the canals, the bacteria can still persist in the complex network of dentinal tubules and micro-canals, which cannot be reached by conventional techniques.

The bacterial flora of root canals consisted predominantly of aerobic and facultative anaerobic bacteria, which party originated from the oral cavity. Generally root infections are mixed infections, which contain eight or more species of bacteria. Typically the polybiotic flora contains approximately the same proportion of gram-positive and gram-negative bacteria, mainly anaerobes. The dominant bacteria are gram-positive cocci that can also survive as a mono-infection have a high resistance to anti-microbiological intervention. The most frequently isolated bacterium was *Enterococcus faecalis* which is a gram-positive facultative anaerobe.

The aim of a root canal treatment is the reduction or elimination of bacteria in the main canal and the adjacent dentin.

ROOT CANAL STERILIZATION

Conventional Methods

Root canal treatment involves cleaning the root canals using mechanical preparation and rinsing with antibacterial solutions and solvents to remove bacteria from the canal system.

Biochemical preparation techniques always produces a smear layer. The smear layer is composed of organic components and consists of dentin chips, remnants of pulp, pre-dentin and odontoblast appendices. The infected pulp remnants will contain bacteria and their by-products also. To remove this smear layer and pathogens, various rinsing solutions are used.

The rinsing of the root canal with antibacterial and tissue solvent substances represents a substantial component of the chemomechanical preparation.

The goals of chemomechanical disinfection are:

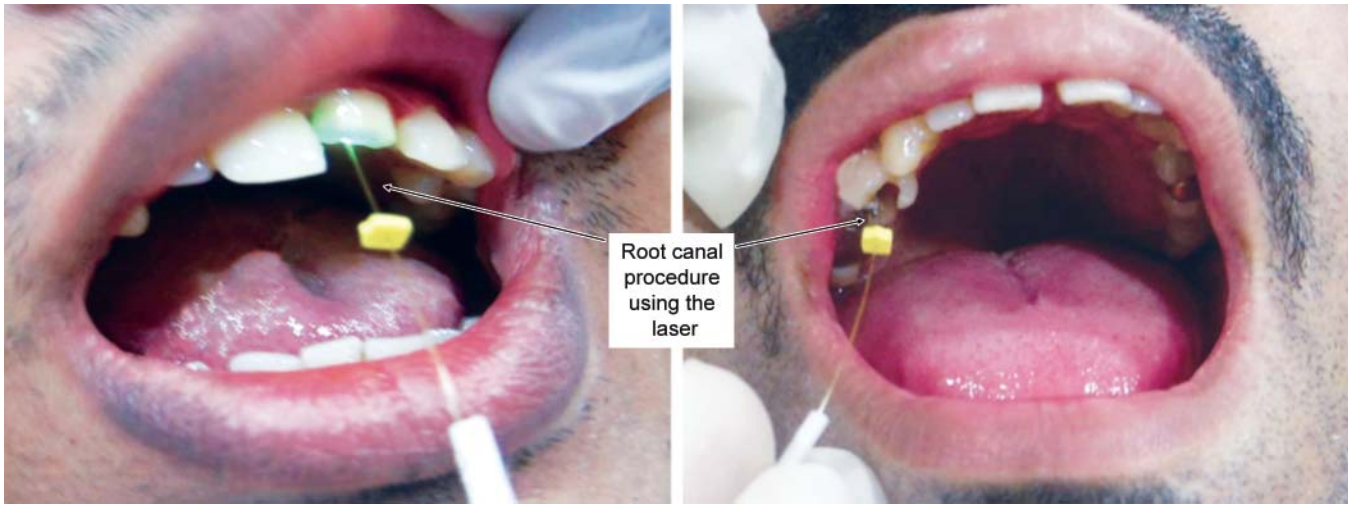
- Killing the bacteria
- Removal of dentinal debris
- Dissolving organic and inorganic canal contents which are not accessible to mechanical removal
- Lubrication
- Low tissue toxicity.

The following materials are used for chemomechanical preparation:

i. **NaOCl:** Dissolves necrotic and vital tissue and exhibits a strong anti-microbial effect. Optimal concentration varies between 0.5% and 5.25%.

ii. **H_2O_2:** A faintly acidic fluid, which disintegrates as an aqueous solution into water and oxygen. Combined with NaOCl releases oxygen and acts as a bubbling rinsing solvent. This help with the evacuation of the dentin and tissue remnants from the apical area. The Nascent oxygen is able to kill the strictly anaerobic bacteria.

Other agents used are chlorhexidine and EDTA.



Figs 9.1A and B: Photographs showing root canal sterilization using 200 micron fiber

Sufficient removal of dentin remnants from the root canal can be accomplished with the above used root canal disinfectants.

Limitations/Disadvantages of Rinsing Solutions

- Bactericidal effect is limited to root canal
- Able to penetrate only a small distance down the tubules because of narrow diameter and high surface tension of the liquid solutions
- Tissue toxicity.

Laser Supported Root Canal Sterilization

Today, lasers are being used in endodontics to dramatically improve the prognosis of root filled teeth. Using suitable wavelengths, together with conventional methods, canal, dentin and periapical regions are being effectively sterilized. Laser associated endodontic procedures are used as standardized therapy. Only those lasers can be used which deliver their power through extremely fine flexible fiber optic systems. These include lasers in the near infrared range. Lasers with a wavelength that can penetrate dentin to a depth and can eliminate bacteria are applicable, because of physical conditions present in a tooth, the Nd: YAG and the diode laser wavelengths are not absorbed in the hard dental substances and are thus effective in the deep layers. The Er: YAG laser acquires its efficiency by photo ablative effect. Hydroxyapatite has its absorption maximum at a wavelength of λ = 2940 nm **(Figs 9.1A to C)**.

Fig. 9.1C: 200 micron laser fiber used for root canal sterilization

Reaction of the Bacteria to Laser Light

Under the use of laser light both biological tissues and individual cell system change their structure. The reaction between photons and molecules depend on the condition of the irradiated cells as well as the wavelength, power density and duration of application. Laser radiation has a bactericidal effect by causing changes in the bacterial cell wall.

The bactericidal effects in the deep dentin layers differ because of the different absorption of the different wavelengths of the lasers. The real problem in endodontics lies in the penetration depth of the rinsing solutions. Laser light, penetrates upto >1000 µm into the dentin. This provides a distinct advantage, since bacteria can immigrate upto 1000 µm into the tubules (Table 9.1).

Table 9.1

Chemical irrigant	Bacteria	Laser
100 µm	~1,110 µm	>1,000 µm

The following describes how bacteria react to irradiation in the depth of the dentin. Bacteria was irradiated indirectly with an Nd: YAG laser. The bacteria showed changes in the cell morphology and corelating cell membrane damage, depending on the dose. Because of complex three-layer membrane, gram-negative bacteria are very sensitive to irradiation, and only very small densities of energy result in severe damage to the cell membrane. An indirect irradiation with ~1.0 W causes obvious changes in the cell membrane. A number of large, vesicle formation of different sizes can be observed (so-called membrance blebbing) which cover the bacteria totally or partly. Even bacteria in which the cell membrane is not destroyed at higher energy (> 1.5 W) show this phenomenon. The blebbing phenomenon probably is the result of the inner layer of the membrane splitting from the two outer layers. The destruction of the cell membrane is due to the impact of direct heat on the bacteria. This damage is enough to stop the growth of the cells and can be reached with very small doses of heat. With the application of multiple irradiations, visible damage of the bacteria can be detected

The quantitative bacteria death increases steadily and the damage depends on a cumulative effect.

A cellular stress factor leads to sublethal, reversible changes, but when the cell is hit again by the irradiation it dies. This mechanism is called the "knock on" effect.

These changes can be seen as a reaction to the irradiation by most of the lasers that are used in endodontics (Nd:YAG, diode and Er: YAG laser).

The bactericidal effect in depth of the dentin has to be different because of the different absorption of the different wavelengths **(Figs 9.2A to D).**

Fig. 9.2A: Preoperative radiograph shows periapical radiolucency in relation to maxillary left central and lateral incisors. The teeth are indicated for re-root canal treatment

Fig. 9.2B: Laser-assisted root canal sterilization. Sterilization of the root canal has been done-using Nd:YAG laser with 200 micron fiber, in continuous circling motion under 1.5 watt, 10 hz. Lesion showing signs of resolution following laser assisted sterilization

DESCRIPTION OF THE DIFFERENT WAVELENGTHS

Nd: YAG Laser

Laser of choice in root canal treatment.

Studies shown that Nd: YAG laser has a bactericidal effect even after passing through a dentin layer of 1 mm at 1 W, 1.5 W. The death of bacteria at higher energy results from total membrane destruction. At lower energy also there is negligible cell growth. The laser has its effect selectively at the membrane structures of the gram-negative bacteria, with the dentin absorbing a small percentage of the radiation. The apical delta can also be reached by the penetration depth of the laser. The Nd: YAG laser has a bactericidal effect in accessory

Fig. 9.2C: Postoperative radiograph after one week. There is marked reduction in the periapical radiolucency

Fig. 9.2D: Postoperative radiograph after three months showing complete resolution of the periapical lesion

(**Figs 9.2A to D:** *Case courtesy: Dr Anita Nitin, Vikram Perfect, Mysore, Karnataka, India*)

canals. A bactericidal effect was obtained that was inversely proportional to the distance between the main canal and the accessory canal. Nd: YAG laser, because of its wavelength and pulsed action, has the highest bactericidal effect of all the lasers presently available. It is a very effective tool for disinfecting the root canal after mechanical root canal treatment since it is the near IR-range and has sufficient penetration depth. The energy is transported by thin, flexible fibers which exists even with diameters of only 200 μm. The radiation of bent and curved canals is possible and the laser tip can also be placed in critical apical areas.

The Nd: YAG laser not only eradicates the microbial flora of the root canal but also has the same effect on the surrounding dentin and its tubules, without affecting the surrounding tissues. It is also used to modify the morphology of the root canal besides disinfection of canal. With the laser, a sealing effect on the root canal wall can be obtained, using the right parameters. With the melting together of the root canal surface with the smear layer, a new homogeneous, flat and recrystallized layer can be produced. The open dentin tubules become closed and sealed.

Diode Laser

It has bactericidal effect similar to Nd: YAG laser. The penetration depth is lower than that of Nd: YAG laser. It also lowers the risk of an unwanted temperature rise. Less efficient in case of very deep infections. Because of similar wavelength, the effect of the diode laser on the root canal wall differs only slightly from the Nd: YAG laser. Diode laser attributes to bio-stimulative effect. Diode laser stimulates cell proliferation and it shows an inhibiting effect on inflammation–propagating enzymes.

Er: YAG and Er, Cr: YSGG Lasers

Er:YAG laser is suggested as an alternative to rotary instruments in the root apex resection **(Figs 9.3A and B).**

Apicoectomies can be performed efficiently with this wavelength, with better postoperational conditions. It has a bactericidal effect through the removal of smear layer in the root canal and is therefore comparable with the chemical rinsing solutions. It could be described as a "physical rinsing". The bactericidal effect is not as good as achieved with the Nd: YAG or diode laser. It can only penetrate the areas closer to the canal lumen because of its wavelength and surface absorption by the dentin and develop an effect on the bacteria **(Table 9.2)**.

ROOT CANAL PREPARATION

The Er:YAG laser is mostly used for canal preparation and shaping the root canal.

Fig. 9.3A: Er:YAG laser unit

Table 9.2

Lasers in endodontics	
Argon laser	488 – 515 nm
Diode laser	805 nm
Nd: YAG laser	1064 nm
Ho: YAG laser	2010 nm
Er: YAG laser	2940 nm
Er: YSGG laser	2790 nm
CO_2 laser	10600 nm

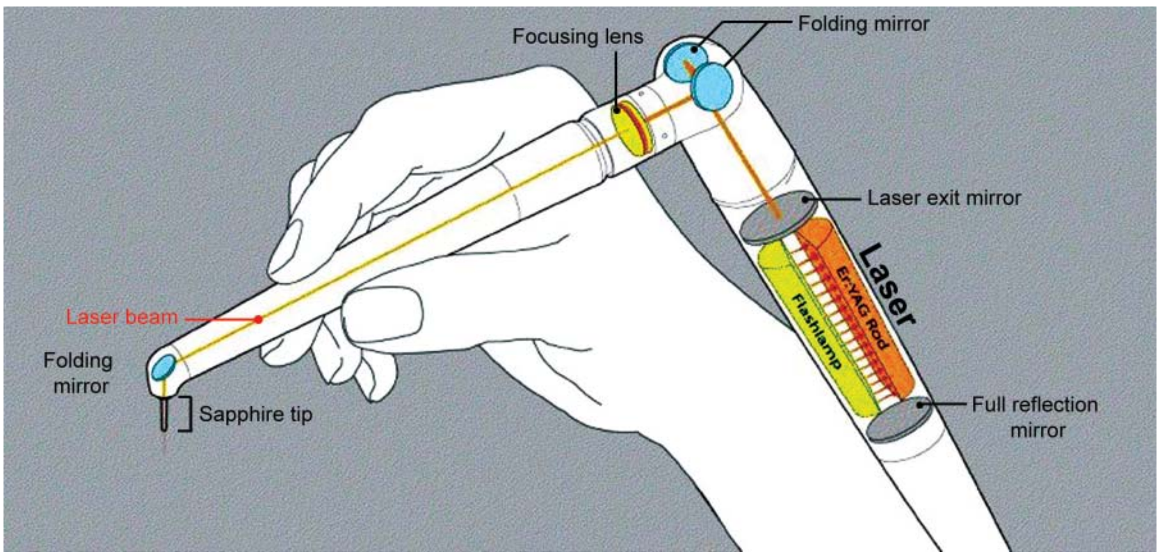


Fig. 9.3B: Schematic representation of the interior of the Er:YAG laser unit illustrated in Fig. 9.3A.

It uses a photoablative action similar to that of cavity preparation (Thermomechanical).

The smear layer that develops during canal preparation has to be removed. During treatment, organic debris adhere to the root canal wall. This smear layer contains microorganisms and bacterial toxins which has to be removed completely.

The Er: YAG laser has the ability to open the tubules completely and remove the smear layer in toto. Because of that, the root canal sealant can then penetrate easily into the canal wall following root canal filling and seal it with optimum results to avoid unstable layer of debris. Additionally, the Er: YAG laser enlarges and extends the root canal lumen without any tension so that the definitive filling is a lot easier to place.

Advantages are less pain and favorable prognosis of the procedure because of complete smear layer removal and bacterial reduction.

The apex sealing and/or the sealing of the dentin openings in the canal lumen by irradiation with this wavelength is more effective and offers a better prognosis for endodontic treatment.

Er: YAG laser in combination with the special fibers is very effective in shaping, cleaning and enlarging the root canal and it seems to be superior in speed and efficiency to the traditional methods. The Er: YAG laser proves to be extremely effective in cleaning the prepared root canals.

APICAL SEALING

Sealing of the root canal tubule is one of the most important factors for a successful prognosis for endodontic treatment and this includes the apical region. Different wavelengths of lasers are capable of sealing surfaces and making them impermeable to bacteria and their toxins. Generally smaller energy levels than that for the conventional sterilization of the root canal are used. Since the fiber remains stationary at the apex for some seconds, thermal stress of the paradontal tissue is avoided. The parameters for energies used to potentially seal the apex vary widely.

Dentin chips, hydroxyapatite or ceramic powder is used to produce a sealed closure with the Nd: YAG laser.

Research and studies indicate that using Nd: YAG laser at 2W power and 20 Hz pulse, within the range of the apical delta, the smear layer can be removed, but also melting and recrystallization can be observed.

Because of the reduced diameter and the number of opened dentin tubules, a decrease in permeability is found in the apical region which is an advantage in endodontic therapy.

SAFETY IN LASER TREATMENT

The higher the energy that is delivered to surrounding tissues by medical lasers the higher is the occurence of irreversible thermal damage to neighboring structures. In endodontics, there is always the question whether any damage to the periodontal tissues occurs during the irradiation of the root canal.

International standards of energy parameters are used with individual lasers, so that the resulting endodontic procedures are harmless to the periodontal tissues and yet provide the optimal bactericidal effect **(Table 9.3)**.

Laser setting (Energy, frequency): Minimal rise in temperature and proven bactericidal effect.

Table 9.3

International standard settings		
Diode laser	Nd: YAG laser	Specifications
2.5 watts	1.5 watts	At defined settings
15 Hz	15 Hz	Correct application in the canal
5 Sec	5 Sec	Defined irradiation time

INDICATIONS

- Chronic apical periodontitis
- Acute apical periodontitis
- Purulent pulpitis and pulp necrosis
- Gangrenous pulpitis
- Periapical abscess
- Apical resorption
- Therapy–resistant long-term failure, i.e. root canal treatment of more than 4 months without improvement of the subjective or objective symptoms
- Combined periodontal endodontic pathology
- Partly sclerosed canals **(Table 9.4)**.

Table 9.4

Limitations
Inaccessible root canals
Complete obliteration of the root canals
Deep root fractures
Non-removable foreign bodies

PRACTICAL PROCEDURE

After medical history and a precise clinical examination with X-ray analysis, the decision about laser treatment is made.

- The root canal treatment is started after placing the rubber dam
- The laser-supported root canal treatment can be arranged into four sections
- Access cavity preparation
- Root canal shaping
- Laser treatment
- Root canal filling.

Access Cavity Preparation

A correctly selected entrance is an important condition for a good preparation.

Anterior teeth and canines, the entrance is chosen from the lingual and/or palatal approach, the incisal edge remaining untouched. Premolars and molars are entered from the central occlusal surface. By using conical rounded diamond burs, the cavity is prepared to the correct depth **(Fig. 9.4A)**.

Fig. 9.4A: Conventional access cavity preparation

After opening the pulp cavity, the pulp roof and the surrounding other parts are extirpated. After that, the canal entrances are searched for with a pointed probe without using pressure.

Root Canal Shaping

It means preparing the root canal for a root canal filling, i.e. removal of tissue remnants and bacteria and extension and shaping of the root canal. Preparation can be done manually or mechanically. It differs depending upon the root canal curvature. For straight canals, manual preparation is chosen and for moderate to strongly curved canals, a combined mechanical – manual method is used **(Fig. 9.4B)**.

Manual Preparation

Divided into two areas depending on the method of preparation.

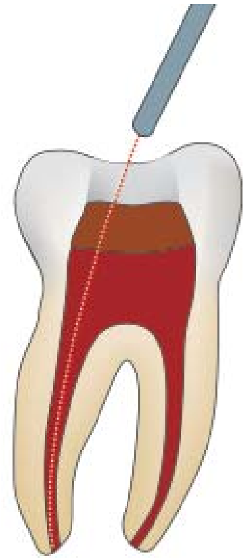


Fig. 9.4B: Determination of working length and shaping of root canal using K-files

The apical coronal method: Setting of the work length and conical preparation of the root canal in the coronal direction (step–back technique).

The coronal-apical method: Conical extension of the coronal root canal portion, setting of the working length and conical extension in an apical direction (step down technique).

After finishing the conventional preparation and rinsing the canal, it is dried with sterile paper points. The laser treatment is now started.

Laser Treatment

Extensive rinsing and drying of the canal with sterile paper points.

All prerequisites are given for the laser treatment.

The laser fiber is inserted into the canal, after the working length has been marked with a rubber stop at the fiber and the laser activated. Special care should be exercised so that the fiber does not remain at the apical stop for longer than one second, since the temperature will rise to critical levels **(Fig. 9.5A)**.

Subsequently, the fiber is pulled from apical to coronal in circling movements to cover the whole root dentin.

This procedure is repeated at least five times.

An experienced dentist can 'feel' the laser, i.e. with the pulsed laser one can differentiate the pulse noise between a wet or dry canal and if there is any incorrect movement of the fiber **(Fig. 9.5B)**.

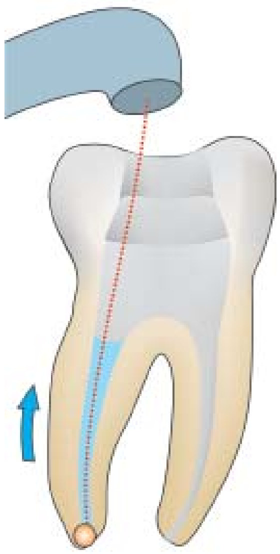


Fig. 9.5A: Laser supported root canal therapy showing the direction of movement of laser fiber

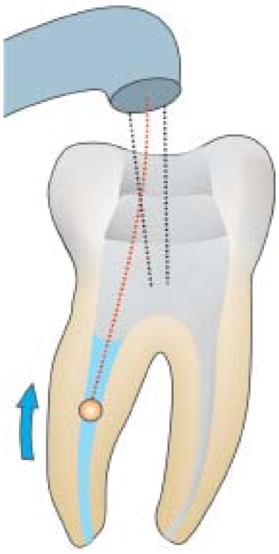


Fig. 9.5B: The fiber is pulled evenly in a circular motion in the apicocoronal direction

After finishing the laser treatment, the canal is filled up with calcium hydroxide and sealed with cavit or GIC to prevent bacterial invasion until the next appointment.

Clinical experience has shown that at least two sessions are needed for optimal laser-supported root canal treatment. Sufficient sterilization of the canal and surrounding dentin is not possible, with a single treatment session.

In some cases the bacteria may actually increase after the first treatment, but after a second session of irradiation, clinical sterilization is achieved.

Root Canal Filling

The goal of root canal filling is:

- To exclude the passage of microorganisms and liquids along the root canal
- To fill out the entire duct systems not only the main canal to the apex but also to close the dentin tubules and accessory canals.

Requirements of Root Canal Filling Material

- Biocompatibility
- Dimensional stability
- Water insolubility
- Small moisture absorption
- X-ray opacity
- Easily applied and easily removed.

At the present time, these requirements are best fulfilled by gutta-percha. The filling is similar to that of conventional methods. After the treatment, a complete X-ray documentation is carried out to monitor the periapical healing in the bone and paradontal tissues.

CHAPTER

10

Laser-assisted Periodontal Therapy

- Etiology, Definitions and Pathogenesis
- Classification of Periodontal Diseases
- Conventional Therapy
- Laser Therapy
- Practical Procedure
- Investigations of the Laser Effects

Nowadays Periodontal disease and their consequences are considered as the main danger for tooth and bone loss worldwide in the group of over 35 years old people.

ETIOLOGY, DEFINITIONS AND PATHOGENESIS

Gingivitis—Periodontitis—Gingival Recession

Periodontal Disease: means bacterially caused inflammatory as well as noninflammatory damage, and thus recessive changes of the gingival and/or periodontal tissue.

Gingivitis

It is defined as "Inflammation of the gingiva in which the junctional epithelium remain attached to the tooth at its original level".

It is reversible by good oral hygiene and consistent plaque control and scaling. It results from bacterial plaque due to lack of proper oral hygiene. Changes of the gingiva are also possible with metabolic disturbances, general illness and side effects of medicine (e.g. Pregnancy, cyclosporin, hyperplasia).

Periodontitis

It is defined as "An inflammatory disease of the supporting tissues of the teeth caused by specific microorganisms or groups of specific microorganisms, resulting in progressive destruction of the periodontal ligament and alveolar bone with pocket formation, recession or both".

Recession

It is defined as the "Exposure of the root surface by an apical shift in the position of the gingiva" **(Table 10.1)**.

Plaque

It can be defined as "The soft deposists that form the biofilm adhering to the tooth surface or other hard surfaces in the oral cavity, including removable and fixed restorations". It is a structured yellowish-gray calculus, which cannot be rinsed off, but must be removed mechanically with a toothbrush or other suitable instruments. It is considered as main cause of periodontitis.

Table 10.1

Etiology
Depends upon several factors:
– Pathogenicity of microorganisms
– Their ability to penetrate into the tissue
– Individually different response of the host
– Depending on patients immune status and his resistance

It consists of Bacteria, which stick together firmly, one with another, through the glycoproteins of the saliva and polysaccharides produced by the bacteria themselves. Gram-positive bacteria settle within the first 24 hours [streptococci, actinomycetes]. With further growth, gram–negative cocci as well as gram-positive and gram-negative small rods and filaments appear. After ~3 weeks, significant increase of filaments particularly at gingival border. Bacterial flora leads the tissue to an intensified immigration of polymorphenuclear leucocytes and exudation into the gingival sulcus. The junctional epithelium is now loosened up in the presence of the developing gingivitis.

Gingival pockets are created due to penetration of bacteria between tooth and epithelium into the subgingival area.

a. **Supragingival plaque** is the main factor in the emergence of gingivitis.

The development of plaque is promoted by natural and iatrogenic plaque promoting factors.

i. **Natural factors:**
- Confining and interlocked position of the teeth
- The enamel cementum border, which shows roughness
- Indentations of root surfaces
- Mouth respiration, because the saliva is more viscous
- Badly accessible pits and fissures.

ii. **Iatrogenic causative factors:**
- Over hanging edges of fillings
- Edges of crowns
- Prosthodontic clips and saddles.

After an average of 10–20 days, firm mineralized tartar develops from the soft plaque.

b. Subgingival plaque:
It is the main factor in the emergence of periodontitis. Two types of subgingival plaque: Adherent and non-adherent.

i. Adherent plaque:
Adherent layer is on the tooth's root surface consists of filaments and gram-positive cocci.
- It calcifies to form subgingival tartar
- It is also called concrement.

ii. Nonadherent plaque:
Consists of loose bacterial accumulation also called 'swimmers', are found on the side of the soft tissue of the pockets.

Consists almost exclusively of gram-negative anaerobic bacteria.

Periodonto Pathogenic Bacteria

The periodonto pathogenic plaque bacteria have certain characteristics, which can accelerate the destruction of the periodontium.

Different bacteria produce specific toxins, whereby endotoxins and exotoxins are differentiated.

Endotoxins are lipopolysaccharides from the wall of gram-negative bacteria, which can cause an increased inflammatory defense reaction.

Exotoxins are antigens, which are produced by the microorganisms, which leads to the decay of polymorphonuclear granulocytes

Pathogenic bacteria are:

Actinobacillus actinomycetem comitans
Bacteroides forsythus
Eikenella corrodens
Fusobacterium nucleatum
Peptostreptococcus micros
Porphyromonas gingivalis
Spirochaetes.

Toxins directly damage the periodontal structures. Actionobacillus actinomycetem comitans is the most important periodontal pathogen. There is chemotactic migration of immune cells.

Secondary causes:

Local factors : Tartar, tooth anatomy, tooth position occlusal trauma, tobacco consumption.

Systemic factors : Metabolic illness
- Diabetes type I
- Avitaminoses such as scurvy

Immune malfunction—Chediak Higashi syndrome
Dermatological problem—Pemphighus vulgaris and lichen ruber planus
Viral illness—Herpetic gingivostomatitis and HIV infection
Genetically caused syndromes—Papillon-lefevre syndrome, Down syndrome **(Fig. 10.1)**.

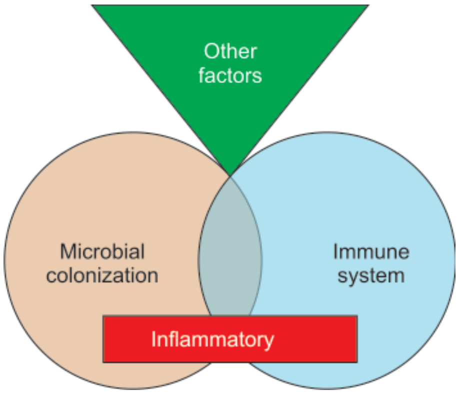


Fig. 10.1: Systemic factors of metaboilic illness

Histology

Divided into four steps:

a. The initial lesion:
1. Develops within 2-4 days.
2. Completely reversible.

b. The early lesion:
1. Develops from an uninfluenced initial lesion within 14 days intensified accumulation.
2. Presents as clinically clearly defined gingivitis.

c. The established lesion:
1. Develops in a few weeks from the early lesion.
2. Appears as chronic gingivitis, which is bound always to the presence of a subgingival plaque.

d. The advanced lesion:
1. Complete healing cannot be achieved despite optimal mouth hygiene.
2. Consequence is the formation of a periodontal pocket.

CLASSIFICATION OF PERIODONTAL DISEASES

Gingivits

The clinical picture is characterized by a reddening, swelling and by a possible ulceration.

An increased flow rate of the sulcus fluid, a bleeding after sounding of the sulcus and increased probing depth without loss of attachment are present.

Types

a. **Plaque-induced gingivitis**
   Systematically modified gingivitis
   – Puberty gingivitis
   – Pregnancy gingivitis
   – Diabetes gingivitis
   – Medicine-induced gingivitis
b. **Nonplaque induced gingivitis**
   - Specific infection:
     Neisseria gonorrhoeae
     Treponema pallidum
   - Systemic illness: Lichen planus, pemphigoid, lupus erythematosus
   - Injury: Chemical, mechanical, thermal.

Chronic Periodontitis

It is the most frequent form of periodontitis.

It is an infectious, inflammatory illness of the tooth retaining apparatus with progressive loss of attachment and dismantling of the alveolar bone.

Main symptoms being pocket formation and gingival recession.

Most frequent in adults starting from fourth decade, can also occur in children and young people.

Etiological factors are usually subgingival tartar and differently associated microflora.

Depending on the extent of infection there are two types of chronic periodontitis:

a. Localized form
b. Generalized form.

Depending on degree of infection we can classify as:

a. Mild—If 1-2 mm loss of attachment present.
b. Moderate—If 3-4 mm loss of attachment present.
c. Severe – If more than 5 mm loss of attachment present.

Aggressive Periodontitis

It is an infectious, inflammatory illness of the tooth – retaining apparatus with rapid loss of attachment.

Its characteristics are the discrepancy between the periodontal destruction and the quantity of etiological factors. Increased proportion of actinobacillus actinomycetem comitans in the subgingival flora increased tissue level of prostaglandin – E2 and interleukin– 1B.

Types

a. **Localized form** which starts around puberty and concerns the first molar and the incisors. It is also called juvenile periodontitis. It causes increased serum antibody titer.
b. **Generalized form** starts around 30 years and concerns at least three teeth other than the first molars or incisors.

Periodontitis as a manifestation of systemic diseases:

Blood diseases:

- Neutropenia, leukemia

Genetically caused sickness:

- Down syndrome, Papillon—lefevre syndrome
- Chediak-higashi syndrome.

Necrotizing Periodontal Diseases

Necrotizing ulcerative gingivitis: limited to the gingiva and is characterized by the occurrence of ulceration and pseudomembranes.

Necrotizing Ulcerative Periodontitis

Acute periodontal infection whereby the necrosis extend to the periodontal ligament and the alveolar bone. It leads to rapid attachment loss, frequently without the formation of deep pockets and sequesters formation.

Abscesses of the Periodontium

Gingival, periodontal and pericoronal abscesses.

Periodontitis in Combination with Endodontic Lesions

Considered to have a certain relationship as a functional unit. Endodontic lesion can spread to cause periodontal disease and vice versa.

Developmental or Acquired Deformities and Conditions

These include factors like occlusal trauma, tooth position, anatomy, restorations, abnormal position of the frenulum and multiplicity of other influences on the gingival and periodontal health.

CONVENTIONAL THERAPY

The aim of the therapy of inflammatory periodontal diseases is mostly complete recovery of the tissue and the re-establishment of anatomical and physiological conditions as much as possible.

An existing gingivitis is reversible with consistent oral hygiene.

With periodontitis, constant controls, motivation of the patient and treatment like root planing, surgical procedures and antibiotics are considered.

The course of treatment of systematic periodontal therapy is divided into three large sections:

- The initial therapy
- The corrective phase (possibly by surgery)
- The supporting periodontal therapy (recall).

Initial Therapy

The goal of initial therapy:

- Removal of gingivitic changes
- Arresting the existing illness
- To obtain plaque and tartar free oral conditions.

Instructions to the patient about oral hygiene measures with appropriate help (e.g. Dental floss, interdental brushes, superfloss).

The motivation of patient co-operation.

The dentist should eliminate possible bacterial hiding places, supernatant filling and carry out professional tooth cleaning to remove the existing supra- and sub-gingival calculus.

The supragingival tartar clings relatively loosely to the tooth surface of the enamel and can be easily removed by scraping with hand instruments such as chisels and scalers.

Ultrasonic scalers can also be used for scaling.

The sub-gingival concrements are intimately bound with the roughness of root cementum and are thus difficult to remove.

For the removal of the infected root cement, granulation tissue and pocket epithelium curettes are used for 'deep scaling'. Universal curettes (e.g. Columbia) and special curettes (Gracey) are used that have a tooth surface specific range of application.

The final polishing and complete removal of discolorations is accomplished by machine driven rotary soft brushes or rubber cups in combination with a few abrasive polishing pastes. A thorough oral prophylaxis smoothens the tooth surface and plaque retention is minimized.

Corrective Phase or Surgical Corrective Measures

After the initial phase, if there are active pockets then corrective phase is used.

Active pockets are characterized by bleeding on careful probing. If the pocket depth exceeds 5 mm, a surgical procedure is indicated.

With flap surgery, the gingiva is mobilized by a sulcular incision and a flap is formed.

Then, under direct view, the root surface is cleaned and the infected pocket epithelium is removed.

Advantage is good visibility and the 'sharp curettage' of the infected soft tissue with a scalpel. Disadvantage is the occurrence of tissue contractions, which can lead to exposed dental necks after healing.

Supporting Periodontal Therapy

Essential component of the periodontal therapy.

Periodontal patients require constant recall and motivation.

Aftercare with repeated supra and subgingival plaque control makes possible, the success of the treatment result obtained in the initial and corrective surgical phase.

LASER THERAPY

Different laser systems have gained more and more significance in the therapy of periodontitis. Lasers within infrared range exhibit excellent antibacterial effect and also deactivate bacterial toxins with recent developments, laser can also be used in the removal of concrements. The power out-put lies clearly underneath a threshold for thermal damage to soft and hard tissues.

Thin, flexible light conductor systems lead the laser beam to almost any desired location facilitating easy use in the area of periodontal therapy. Before lasers can be applied the patient must be prepared with complete initial therapy **(Fig. 10.2)**.

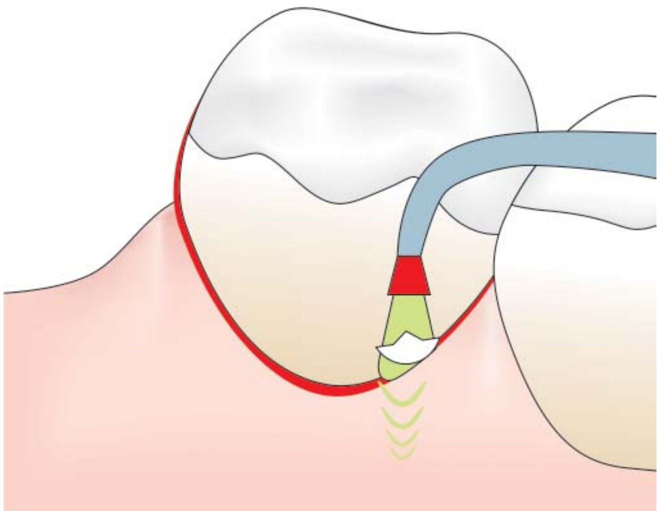


Fig. 10.2: Diagrammatic representation of laser assisted periodontal therapy

Applied Lasers

Common lasers used in periodontal therapy are:

Nd: YAG laser (λ = 1,064 nm)

Diode laser (λ = 810 or λ = 980 nm)

Both lasers (Nd: YAG and Diode) work with flexible light conductors, which make application possible in periodontal pockets. With development of special applicators, employment of lasers, whose indications were limited to the preparation of tooth hard substance, was made possible in the area of periodontics.

Impact of Different Lasers on Tissues

The most important effect of all lasers is their antibacterial effect. With low power settings, extremely satisfying results can be obtained. Er: YAG laser is capable of removing concrements from the root surface. The frequency double alexandrite laser also provides similar benefits.

If the output is increased, pocket epithelium can be removed with the Nd: YAG or diode laser.

Laser facilitates complete de-epithelization in contrast to conventional methods.

It can be used in flap surgery if the settings are higher.

Advantage: Nd: YAG and diode wavelengths permit efficient cutting and coagulation.

A more rapid and less complicated healing.

Depending on the power setting and penetration depth, the laser light becomes attentuated when passing through the irradiated tissue down to energy densities that correspond to the irradiation of a soft laser.

It produces effects, like cell stimulation and pain inhibition.

Diode Laser

Diode laser has excellent bactericidal effect.

Effective on the periodontal, problem bacillus, *Actinobacillus* actinomycetem comitans.

Diode laser is an effective and a useful addition to the conventional instrumental treatment. It is a good alternative to chemical rinsing solutions in order to reduce further bacterial load **(Fig. 10.3)**.

Fig. 10.3: Example of a diode laser machine

The inflammation of the tissue can be reduced with diode laser in combination with a scaling therapy. The diode laser does not have a significantly positive effect on the reattachment of periodontally damaged teeth. Diode lasers should only be applied as adjuvant therapy subsidiary to hand instrumented or ultrasonic supported cleaning of the root surface.

Bleeding periodontal pockets produce a blood layer on the root surface and thus lead to destruction and carbonization of the dental hard tissue due to the high absorption of the diode laser's wavelength in hemoglobin.

Because of this, the periodontal pocket should be sufficiently rinsed with sterile saline solution or further treatment should be postponed by at least one day.

Thus, the diode laser is certainly superior to chemical rinsing solutions for reduction of bacteria and its wavelength can be regarded as a valuable tool in the field of periodontal therapy.

It is important to keep the fiber in motion and never stationary to prevent thermal side effects.

In this way, the diode laser does not produce damage to periodontal hard and soft tissues, but leads to the desired therapeutical modifications.

Fig. 10.4: Example of Er:YAG laser unit

Nd: YAG Laser

The Nd: YAG laser ($\lambda = 1,064$ nm) has a good antibacterial effect.

The short-wave infrared range wavelengths do not show absorption in hard tissues.

Nd: YAG laser is also indicated in laser supported removal of pocket epithelium. Only with high laser energies outside the therapeutic range, melting and cracks in the root can be observed.

Effects of Nd: YAG Laser on Periodontal Tissues

- An output of 1.25 – 1.75 W, a pulsed Nd: YAG laser is suitable to remove the pocket epithelium of moderately deep pockets.
- Application of Nd: YAG lasers even with low energy, leads to changes in the root surface **(Fig. 10.4)**.
- Nd: YAG laser applied with 2.19 W – the concrement at the root surfaces was completely removed with no damage on the root surface.

The applied pulsed Nd: YAG laser with low energy leads to an elimination of those bacteria that are in close relationship with the development and progression of periodontitis.

The antibacterial effect was obtained with low energy [1W] with best results:

- At these energy settings no cementum damage was seen.
- At higher energies, melting and cracks on hard tissues was seen.

Nd: YAG laser is very effective in removing the smear layer. There is a substantial rise of temperature - intra-pulpal temperature from 9° to 22°C and surface temperature from 18°C to 36°C.

- An output of 1.25 – 1.75 W, a pulsed Nd: YAG laser is suitable to remove the pocket epithelium of moderately deep pockets.
- Application of Nd: YAG lasers even with low energy, leads to changes in the root surface.
- Nd: YAG laser applied with 2.19 W – the concrement at the root surfaces was completely removed with no damage on the root surface.

Studies of the Nd:YAG laser showed that at higher energy levels, the subgingival deposits were removed effectively. The laser has larger effects on the removal of concrement than on the cementum and dentin. The root cement and the exposed dentin were not affected by the laser treatment with settings of 50 mJ. Changes in the root surfaces increased with rising energy; with 1 mm distance, cracks and fissures in the cement were observed **(Figs 10.5A to C)**.

Advantages of Nd: YAG Laser Application

- Nd: YAG is a very valuable tool in periodontal treatment.
- Reduces pain
- Improvement in concrement removal
- Hemostatic effect of laser irradiation

Fig. 10.5A: Initial examination shows gingival inflammation and bleeding on probing

Fig. 10.5B: Insertion of the laser fiber into the periodontal pocket

Fig. 10.5C: Postoperative photograph after one week showing complete resolution of the inflammation

- Elimination of periodontopathogenic germs
- Removal of the pocket epithelium
- Reduction of interleukin – 1β, which has stimulating effect on the bone absorption.

What the diode and Nd: YAG lasers have in common is that, both wavelengths can be delivered directly to the application place with the help of extremely thin, flexible light conductors. Thermal side effects can be excluded when right parameters and procedures are used **(Table 10.2).**

Table 10.2

Activation of laser	
Diode laser – 2.5 watt	**Nd: YAG – 1.5 Watt**
10 ms pulse duration	10 ms pulse duration
50 Hz	50 Hz
Er: YAG – 100 mJ at 15 Hz	
for Gingivectomy increase to ~3 W	
Sweeping motion form apical to coronal	
Sufficient amount of water	
Irradiation time / Interval : 5 s, at least 15 s interval	

CO_2 LASER

CO_2 laser with wavelength of 10,600 nm has shown positive effects with regard to its bactericidal impact and the ability to remove pocket epithelium and to condition the root surface CO_2 laser applied with low power settings conditions the root surface. Study shows that the CO_2 laser was used in defocused mode, the formation of cracks and craters on the root surface could be prevented. Conditioned surface was smooth and open dentinal tubules were sealed **(Figs 10.6A and B)**.

Er: YAG Laser

The Er: YAG laser exhibits excellent anti-bacterial effect.

It is also possible to remove concrement and plaque from root surface. In order to exclude thermal damage of the irradiated surfaces, sufficient water cooling should be provided along with its application.

Fig. 10.6A: Chronic gingivitis case with inflamed gingival margins

Fig. 10.6B: Patient recalled one week after laser-assisted periodontal treatment. Notice the rapid healing and establishment of healthy gingival attachment

Effects of an Er: YAG Laser on Periodontal Tissues

Er: YAG laser represents a suitable aid to the removal of concrement when used with water irrigation, an energy of 30 mJ per pulse and a frequency of 10 cycles per second.

Er: YAG laser seems to be very effective in the removal of subgingival plaque and concrement:

- Energy of 100 mJ is applied, where the roughness at the root surface is comparable with that caused by manual scaling.
- The temperature rise in pulp chamber may be tolerable, if appropriate water cooling is present and an interval of 15 s respected.

Er: YAG laser with a lower energy setting in combination with a delivery system is quite comparable with the conventional instrumentation with regard to concrement removal.

Depending on the energy setting used, the Nd: YAG and the CO_2 lasers produced melting and cracks on the root surface. In contrast, the Er: YAG laser irradiation led to the roughening of the root surface and the exposure of collagenous fibers.

The Er: YAG laser offers better adhesion of fibroblasts than complete manual cleaning.

Study showed that an irradiation with power setting of 60 mJ at 10 Hz was more beneficial to the establishment of fibroblasts than scaling or laser irradiation with higher energies.

Uses:

Er: YAG laser is very useful in soft tissue surgery and as an alternative to instrumental scaling because of absence of complications and side effects after surgery.

In nonsurgical periodontal therapy with Er: YAG laser → After evaluation there was reduction in plaque index, gingival index, bleeding index, the pocket depths, the gingival recession and the clinical loss of attachment.

The attachment gain after the laser irradiation is comparable to the one achieved by ultrasonic scaling.

Er: YAG laser can also be used in surgical and regenerative periodontal therapy.

Er: YAG laser facilitates an effective treatment of hypersensitive dental necks.

Laser fluorescence at a wavelength of $\lambda = 655$ nm is suitable for the detection of subgingival concrements.

The Er: YAG laser is only at the beginning of its success in periodontal therapy.

The advantages seem to outweigh the disadvantages.

Laser is surely the best alternative to conventional instrumental treatment, since laser provides painless and rapid treatment to the patient.

Advantages of Er: YAG Laser

Highly effective in concrement removal.

An improvement of the reattachment can be achieved.

It offers a better environment for the adhesions of fibroblasts.

The rise in pulpal temperature induced by the laser can be neglected when using appropriate parameters and water cooling.

Frequency-doubled Alexandrite Laser

It could revolutionize the entire range of laser based periodontal therapy.

Selective concrement removal with a good antibacterial effect under maximized preservation of the root surface.

An easy applicability makes this laser appear to be ideal tool in this field.

PRACTICAL PROCEDURE

Initial Diagnosis and Evaluation

It begins with the collection of a general medical and dental history in order to evaluate periodontal pathogenic relevant basic illnesses and to evaluate the general condition.

Special attention must be focused on the recognition of occlusal disturbances and periodontally unfavorable restorations.

Assessment of

- Pocket depth
- Mobility of the teeth
- Plaque accumulations
- Severity of the inflammation
- Radiographic findings
- Restorations/periodontal compatibility.

Periodontal probes for measuring pocket depth mark an estimation, not only of the actual pocket depth, but also of general attachment loss.

The Grade of tooth mobility is recorded following a scale from 0 (normally stable) to 4 (extremely high mobility).

Several indices are used to assess plaque formation quantitatively such as -

Plaque index, Hygiene index, Gingival index, Papillary bleeding index are used in order to assess the severity of periodontitis:

Indices like Periodontal disease index [PDI] or the Community Periodontal Index of Treatment Needs were developed to evaluate the attachment loss besides the grade of inflammation.

Radiological examination like OPG, bite wings are also very important.

Clinical Preparation

Initial therapy includes tooth cleaning and curettage to remove plaque and concrements.

Overhanging fillings are eliminated.

Patients are guided with proper oral hygiene measures **(Figs 10.7A to G)**.

Aim of Treatment

- Removal of plaque/calculus
- Bacterial reduction
- Removal of infected tissue

↓

- Elimination of inflammation
- Prevention of further plaque formation
- Regeneration of periodontium.

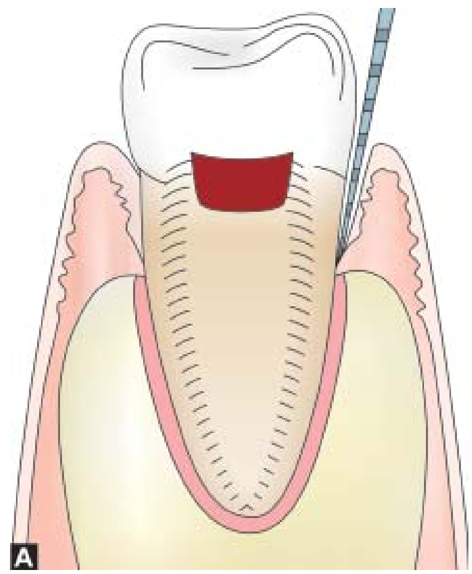


Fig. 10.7A: Determination of pocket depth using periodontal probe

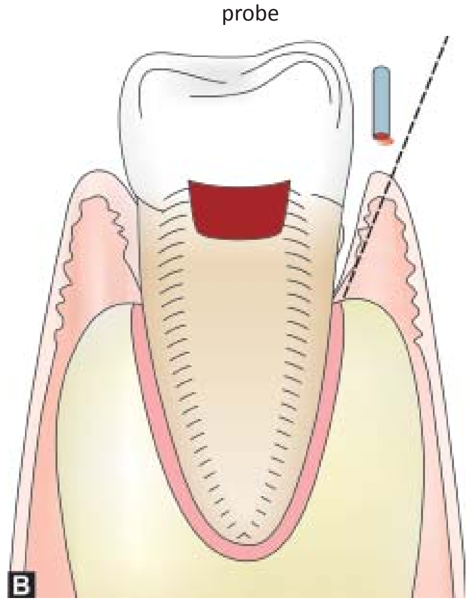


Fig. 10.7B: Pulsed laser irradiation selectively dissects epithelium, denatures diseased tissues and pathological proteins

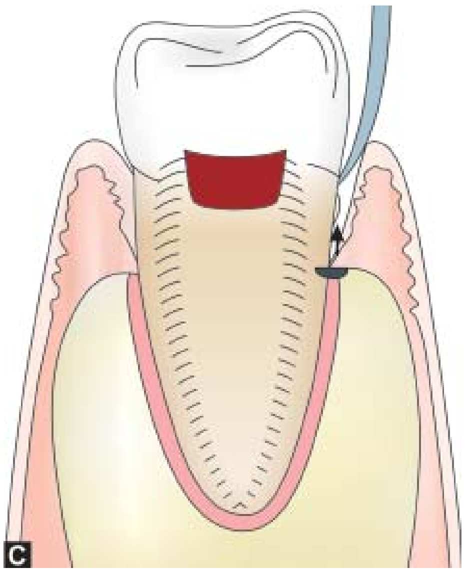


Fig. 10.7C: Removal of concrements and tartar using ultrasonic scalers and special hand instruments

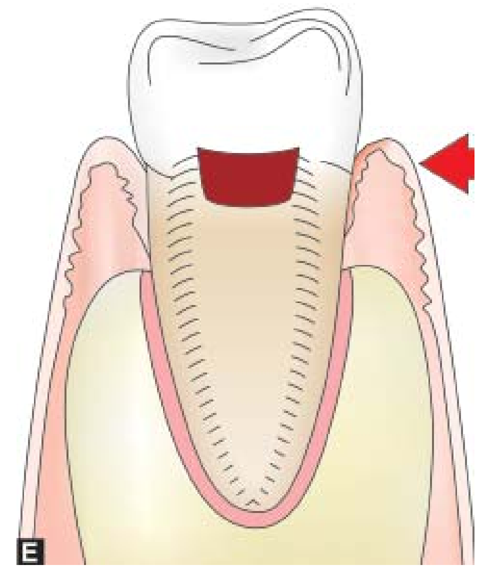


Fig. 10.7E: Compression of gingival margin against the root surface after surgery to facilitate the formation of static fibrin clot at the gingival crest

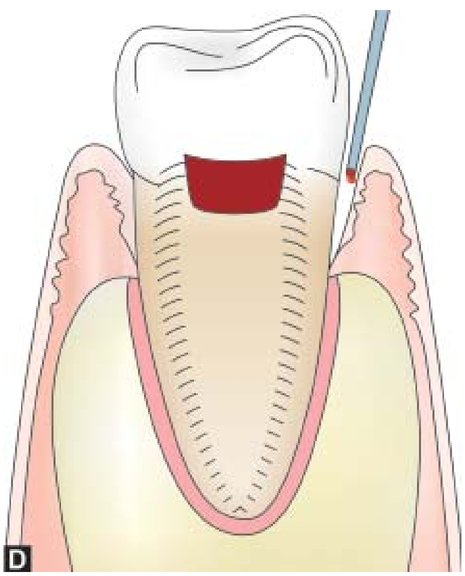


Fig. 10.7D: Laser furnishes pocket debridement and establishes coagulation

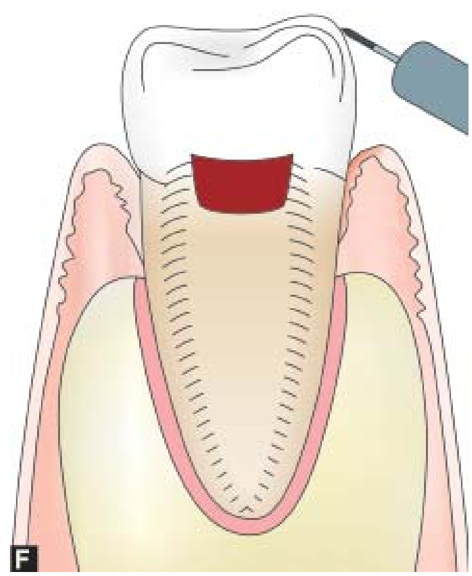


Fig. 10.7F: Occlusal adjustment done with diamond points to prevent trauma from occlusion

Laser Therapy

Due to initial therapy – A large extent of tartar and concrements are removed.

Laser radiation can exert its optimal effect at the target destination.

Safety goggles a must for patient and doctor **(Figs 10.8A to I)**.

The light conductor (a fiber with diameter between 200 to 400 μm) is introduced without use of force, like a probe, step by step into the periodontal pocket.

After the activation of the laser, the fiber is removed from the bottom of the pocket by sinusoidal movements to the outside of the pocket within 5 s.

This is necessary in order to irradiate, on one hand, as much as the root surface as possible and on the other to avoid localized overheating.

The choice of laser parameters is of great importance. For pocket disinfection:

- Nd: YAG laser is used with a setting of maximally. 1.5 W with 15 Hz
- Diode laser – maximally 2.5 W with 15 Hz

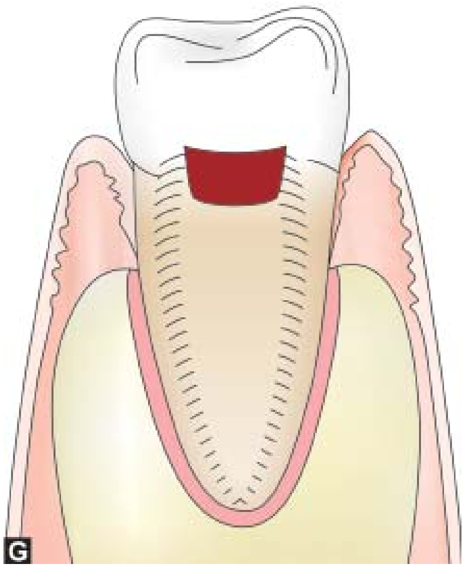


Fig. 10.7G: Reattached gingiva postsurgery

Fig. 10.8C: Ceramic scissor. The tip of the fiber should be cleaved following every case to ensure that laser is ready for the next procedure

(Note: Cleaving removes the scratched part of the fiber optic cable exposing a fresh, highly polished cable surface. This helps transmission of the laser energy to the tissue more efficiently.)

Fig. 10.8D: Diode laser handpiece with metal guides

Fig. 10.8A: Laser cable stripper

Fig. 10.8B: Stripping of the laser cable

(Note: Poststripping, ensure the cleave leaves no sharp edges by shining the cable against a flat surface and confirm that the aiming beam describes a circular pattern without a 'comet tail' or oval appearance.)

Fig. 10.8E: 400 micron cable used for periodontal treatment

Fig. 10.8F: Fiber optic cable being fed through the handpiece

Fig. 10.8G: Metal guide being fed to the hand piece

Fig. 10.8H: 3 to 4 mm of the fiber optic cable should extend from the end of the guide

Fig. 10.8I: Safety goggles

These values ensure high-grade antibacterial effect with minimal thermal side effects.

To accomplish gingivectomy-higher settings can be chosen, upto ~3 W for both wavelengths.

Incase of Er: YAG laser, a setting of 100 mJ at 15 Hz should not be exceeded because this setting ensures sufficient concrement removal at a reasonable temperature rise.

If all the four sides of a tooth were irradiated, the doctor begins again with the first quadrant, repeats the entire procedure until each side has been treated five times for 5 s.

In most cases the treatment is comfortable and not painful to the patient, local anesthesia is rarely necessary.

In order to ensure and perpetuate therapeutic success, a regular recall and monitoring of the mouth hygiene, in the sense of maintenance therapy, is absolutely necessary.

Also, a periodic repetition of the laser irradiation after 3-6 months can sometimes be useful.

The aim of recall appointments is not only a check-up of the oral hygiene, but also facilitates a re-evaluation of the treatment applied thus far and its success.

Surgical procedure with laser therapy could be necessary if a conventional therapy in conjuction with a laser therapy does not yield desired success **(Figs 10.9A to E)**.

INVESTIGATIONS OF THE LASER EFFECTS

- Scanning election microscopy
- Temperature measurements
- Light microscopy
- Surface alterations
- Impact on dental pulp
- Impact on soft tissues.

Fig. 10.9A: Patient came with a complaint of swollen gums. History revealed drug-induced gingival hyperplasia. Maxillary and mandibular anterior view

Figs 10.9B and C: Gingival hyperplasia in relation to maxillary posterior region

Fig. 10.9D: Immediate postoperative photograph (anterior view)

Fig. 10.9E: Postoperative view of the posterior teeth after one week

CHAPTER

11

LASER IN ORAL AND MAXILLOFACIAL SURGERY

- Introduction
- Conventional Therapy
- Laser Therapy
- Advantages and Disadvantages of Laser-assisted Oral Surgery
- Techniques for Laser Use in Oral and Maxillofacial Surgery
- Laser in Implant Dentistry
- Cosmetic Facial Laser Surgery
- Laser-assisted Routine Clinical Procedures
- Laser-assisted Biopsy

INTRODUCTION

Lasers were used first for surgeries; the lasers were also used routinely within the field of dentistry. At least ten different laser types of various wavelengths can be chosen in surgery depending on the tissue and its location.

Besides "traditional methods" such as scalpel, cryo-surgery and electrical surgery in the sense of diathermy (Endothermy), laser surgery can be considered as the fourth option by the dentist **(Table 11.1)**.

Table 11.1

Surgical methods available today
Scalped
Diathermy
Cryotherapy
Laser

Specific Surgical Problems

Surgical Problems include:

1. Sterility and its maintenance during surgery.
2. Restricted spatial conditions.
3. Direct neighborhood of different tissue.
4. Intraoperative bleeding.
5. Scars.
6. Reduced operability due to systemic diseases which may compromise the patient for surgery.
7. Complications in wound healing.

Sterility, Duration of Operation and Re-invasion of Germs

The intraoral flora consists of ~50 million germs, representing over 300 different species. Due to the special milieu in the oral cavity, the establishment of sterile conditions during operational interferences causes a problem which is sometimes almost impossible to solve. With increasing operation duration, there is danger of re-invasion of the operating area from the remaining micro-organisms.

Restricted Spatial Conditions

- The natural orifice of the mouth limits the unhindered view of the operating surgeon to the area of operation
- Especially with very young patients (cleft palate in babies) this lack of space places enormous burden on the surgeon
- Control of intraoperative bleeding or other problems that occur, are also more difficult due to the size restraint of the area.

Direct Neighborhood of Different Tissues

While performing simple routine operations, the tissues may be of very different hardness, changing water content and differing pigment content necessitating a very frequent instrument change or a very narrow spectrum of wavelength, used in order to obtain only the desired effects in the specific tissues.

While using laser types, the correct choice of power settings regulates the effect that can be obtained in the single tissue.

Intraoperative Bleeding

Even with very careful preparation, the anatomic variants of some vessels in the maxillofacial region and rich collateralization, offer a permanent source for the risk of intraoperative bleeding in almost all tissues in this region. The extent of bleeding considerably limits the view of the operating surgeon and causes an additional psychological stress.

Postoperatively, the hematoma leads to additional edema and swelling forming the ideal nutrient medium for bacteria that cause postoperative infection. Antibiotic therapy is needed postoperatively.

Scars

Scar formation represents one of the most substantial postoperative problems.

The development of scars is not totally predictable. Conventional surgery normally has to be done with sutures at the end. In the context of maxillofacial regions, often functionally important regions in the mouth are concerned. It may reduce the quality of life of the patient considerably and may lead to malnutrition or psychological defects due to social isolation.

Reduced Operability due to Systemic Diseases which may Compromise the Patient for Surgery

Different internal systemic diseases such as hemophilia, hematological malignomas, etc. often represent a contra indication to surgery.

Complications in the Wound-healing Process

One group of patients with higher operation risks are those who might develop wound-healing complications due to their internal diseases: diabetes mellitus, uremia, vitamin deficiency syndromes, etc. which often lead to delay in the healing process.

Corticosteroids decrease the collagen synthesis thus disturbing the wound healing.

CONVENTIONAL THERAPY

Conventional therapy includes the use of scalpel, electrotomy and cryosurgery.

Scalpel

Use of scalpel offers the advantages of easy handling and minimal trauma to the surrounding tissues.

The main problem with the traditional intraoral surgery remains the maintenance of sterile conditions. Bleeding must be stopped by surgical procedures or by means of electrocoagulation. Only germ reduction in the oral cavity is achievable and depending on surgical duration, the germ in the area of intervention increases during surgery. In the field of oral as well as maxillofacial surgery, the preparation of different tissues is only possible by using larger number of equipments (scalpel, shears, milling tools, drill, chisel, etc.)

This leads to a time consuming, complex mobilization of the surrounding tissues particularly with large defects, creating mucogingival interpolated flaps or distant flaps. Changes in the mucosa quality can arise by conditioning or excision and replacement by new tissues.

Wound closure in extended defects is achieved by means of suture fixed Iodoform strips, which supports the process of granulation and provide wound protection during nutrition.

Electrotomy

The main advantage of electrotomy lies in perfectly unstressed cutting of the soft tissue.

The hemostasis due to heat development causes a very clear view of the operation field, suggesting the primary area of application of this technology to strongly vascularized tissues and/or tumors.

The Joule's heat developing at the electrode is responsible for the decreased bleeding, increased asepsis and less tumor cells spreading. This heat responsible for the desiccation effect, causes necrosis of the surrounding tissue.

An advantage of electrical surgery is the execution of excision and coagulation with single instrument.

Ending electrosurgical interventions also means application of bandage plates or iodoform strips for wound closure.

Cryosurgery

Hemangiomas represent the main operational area for cryosurgery. A disadvantage of this technique is the multiple sessions, performed once every 4 weeks, permitting progress only from session to session. Also hyperkeratosis can be eliminated by cryosurgery. Small defects are entrusted to granulation.

LASER THERAPY

Lasers have played an integral part in the evolution of the practice of oral and maxillofacial surgery. The reason for this transition is simple: many procedures can be executed more efficiently and with less morbidity with use of lasers when compared with the scalpel and electrocautery. Access to small, portable office based lasers that use improved intraoral delivery systems has made it possible for even minor routine procedures to be performed with lasers. Other procedures have become associated with lasers because of its inherent advantages for those specific procedures.

Because of its excellent affinity to all water based tissues, the carbon dioxide (CO_2) laser at 10,600 nm wavelength has long been used in oral and maxillofacial surgery. It is an ideal wavelength for most soft tissue surgeries performed intraorally and extraorally.

Currently, most applications of laser in OMFS are restricted to soft tissues of the face and oral cavity. The most commonly used lasers are the CO_2 and Er: YAG, both of which are absorbed primarily by water. The photothermal effect plays the most significant role **(Figs 11.1A to C)**.

By adjusting the power density and energy density, it is possible to create a deep thin cut into tissue for incision or excision or a wide superficial surface

Fig. 11.1A: Example of a CO_2 laser unit

Fig. 11.1B: Accessories for CO_2 unit

Fig. 11.1C: Articulated arm of the CO_2 unit

vaporization for tissue ablation with least collateral damage. Another important facet of laser uses in OMFS is the type of delivery system. Fiberoptic delivery is ideal and allows an endoscopic view. But CO_2 lasers cannot be passed through traditional quartz fiber. Hence, the advent of flexible hallow wave guide technology has enabled surgeons to access all areas of the oral cavity with ease.

ADVANTAGES AND DISADVANTAGES OF LASER-ASSISTED ORAL SURGERY

Advantages

- Maintenance of sterile conditions
- Hemostatic nature of laser allows surgery to be performed more precisely and accurately because of increased visibility of the surgical site. CO_2 laser can seal blood vessels of approximately 500 ▯ or less.
- Decreased postoperative swelling is characteristic in laser use. Decreased swelling allows for increased safety when performing surgery.
- Tissue healing and scarring also are improved with the use of the laser due to a combination of decreased lateral tissue damage, less traumatic surgery, more precise control of the depth of tissue damage. Laser wounds heal with minimal scar formation and intra-oral laser wounds often can be left unsutured.
- Decreased postoperative pain
- Hollow wave guide technology and fiber optics maker the laser accessible to almost any area of the oral cavity
- Reduction in number of instruments
- Low costs by reduction of material, staff and time.

Disadvantages

- Healing from laser surgery is usually excellent, with decreased scarring and increased function, but the speed of healing is usually prolonged when compared with others types of wounds.
- This delay in healing is due to the sealing of blood vessels and lymphatic.

TECHNIQUES FOR LASER USED IN ORAL AND MAXILLOFACIAL SURGERY

There are basically three photothermal techniques for laser use on soft tissues within the oral cavity and on the face:

A. Incision and excision
B. Ablation or vaporization
C. Hemostasis.

Incision and Excision

A common use of lasers in OMFS is to use the device essentially as a light scalpel, using the laser to make relatively deep, thin cuts. This technique allows the surgeon to perform almost any intraoral procedure such as incisional or excisional biopsy, lesion removal or incision for flap access.

This technique would require a fairly high power density using a small spot size to create a deep but thin cut, as would be needed to make an incision.

It is generally ideal to keep the spot size to the smallest practical size possible with a particular laser because this result in the thinnest cut, closely replicating the cut made with standard scalpel blade **(Fig. 11.2)**.

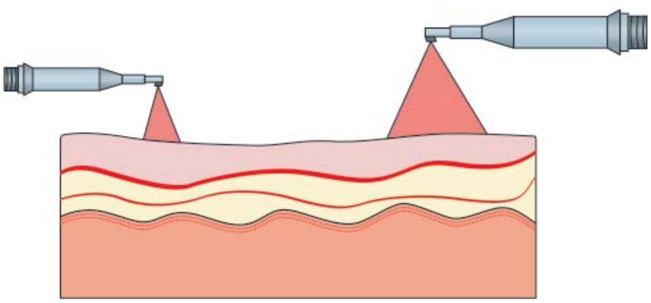


Fig. 11.2: Diagrammatic representation of the effect of distance of laser beam on the spot size at target tissue surface

The method of surgery varies depending on the type of delivery system being used.

The basic technique for incision and excision remains the same. It is always a good idea to begin the procedure by outlining the intended incision line.

The outlining can be done on most machines by using an intermittent, pulsed or gated mode with a rate of 10 to 20 pulses per second and low fluence per pulse to allow superficial mark on the surface of the target without deep penetration.

Once this procedure is completed, the laser can be put into continuous mode and the dots can be connected to create the desired incision. This connection should be done in a rapid continuous fashion to create a single depth cut with minimal adjacent thermal damage. The procedure can be repeated until the appropriate depth is reached. Using typical spot sizes of 0.1 to 0.5 mm, a power of 4 to 10 W usually is a good level to initiate treatment for most intraoral lesions — spot size should not be adjusted for incisions.

Once the appropriate depth has been reached, excision can be performed by grasping the tissues with forceps, applying slight traction and horizontally undermining the tissue in the same fashion with the laser in focused mode.

Closure of incisions and excisions performed with a laser results in healing with minimal bleeding, scarring and postoperative pain.

One modification of this technique is the use of laser for implantology. The CO_2 laser incisional mode can be used safely to uncover the implants as long as care is taken to prevent conduction of heat from surrounding tissues back into the implant.

Another excellent use is removal of any hyperplastic peri-implant tissue. This removal is accomplished easily by maintaining the tip of the laser parallel to the long axis of the implant and running the laser around the implant body.

List of examples of typical lesion treated by excision and incision: Fibroma, mucocele, papilloma, gingival lesions, incisional biopsy, excisional biopsy, vestibulo-plasty, peri-implants, tongue lesions, malignancy removal, etc.

Laser excision is desirable for any solid, exophytic type lesion. It is also excellent for tissue removal for preprosthethic surgery.

Ablation and Vaporization

The laser excels in performing vaporization procedures. Tissue ablation (also called tissue vaporization) is used when the surgeon wishes to remove only the surface of the target or to perform superficial removal of tissue over a larger area. The most common examples for intraoral use are mucosal lesions such as leukoplakias, dysplasias and papillary hyperplasia. The lesions are confined to the epithelium or to the epithelium and superficial subjacent submucosa.

It is possible to manipulate laser to confine removal to just the involved layers with minimal damage to underlying tissues and structures.

In contrast to incisional procedures in which the spot size is kept small, vaporization is accomplished by using larger spot sizes, which decreases significantly the power density and subsequent depth of effect, while increasing the width of laser, allowing large areas of tissue to be covered in a relatively short period **(Fig. 11.3)**.

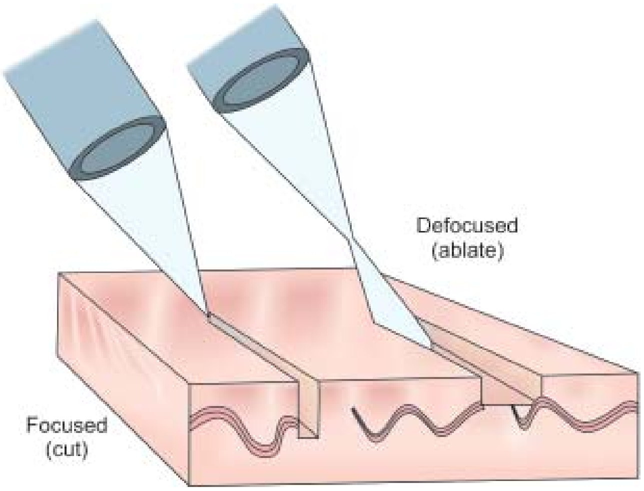


Fig. 11.3: Diagrammatic representation of the effect of focused and defocused laser beam on target tissue. Focused beam results in a well-defined incision whereas a defocused beam causes ablation

The technique for vaporization begins with the same outlining procedure that is used for excision. This approach allows the surgeon to demarcate clearly the extent of vaporization in a controlled slow fashion using an intermittent pulsing mode. At this point, the laser is defocused by pulling the laser back from the target and allowing the beam to widen.

A spot size of 1.5 to 3 mm is typical for most intraoral vaporization procedures and provides a reasonable area of coverage.

The defocused beam is then transversed along the lesion in a series of vertical strokes, represents side by side 'L's.

The clinician must not overlap excessively or miss any areas and must maintain a constant speed of transverse to maintain a uniform penetration depth.

Subsequent to each pass, any surface charring should be removed gently with a wet gauze, because this layer contains no water for absorption of the laser beam and results in prolonged heating and excess lateral thermal conduction.

This technique allows for removal of surface lesions in layers of a few hundred microns to 1 to 2 mm at a time visualization of tissue anatomy is excellent, owing to the hemostatis and the surrounding layers are identified easily. By removing the epithelium, less damage is done to underlying tissues and the risk of inadvertent damage to underlying nerve or blood vessel is minimal.

Ablation can be used when small amounts of tissue need to be removed regardless of whether they are superficial or not. The standard technique of defocused ablation is used, e.g. during apicoectomy.

Ablation techniques preclude an excisional biopsy of the specimen. If the lesion turn out to be benign, it can be ablated, if malignant the procedure can be changed to laser excision.

A list of typical lesions treated by vaporization is leukoplakias, lichen planus, dysplasia, hyperkeratosis, tissue hyperplasia, etc.

Hemostasis Techniques

The use of CO_2 laser generally results in a bloodless surgical field. The laser can be used as a hemostatic tool to stop the bleeding in the field and to allow for similar postoperative wound management. The cause of this effect is not coagulation but rather the contraction of the vascular wall collagen. This contraction results in constriction of the vessel opening and hemostasis. Before beginning lasing of the tissue for hemostasis, ensure a relatively dry field.

The technique used generally is similar to vaporization but uses a small spot size (somewhere between the focused beam used for incision and defocused beam for ablation). The laser is passed over the tissue similar to vaporization procedure, until bleeding ceases. If bleeding continues, it is an indication that a vessel greater than the possible lateral thermal zone of the laser is involved and this requires standard hemostatic techniques to arrest the bleeding.

It is used in the removal of vascular lesions of the oral cavity such as capillary and cavernous hemangiomas. It is usually treated easily with a CO_2 lasers by merely excising the lesion in total with sealing of the feeding vessels by the laser as it performs the excision. The ideal laser to use in most circumstances is the one whose wavelength matches the target tissue best (Table 11.2).

Table 11.2

Indications for lasers used in dentistry					
Indication	CO_2	Nd: YAG	Diode	Argon	Er: YAG Er, Cr: YAG
Gingival surgery	✓	✓	✓	✓	×
Preprosthetic surgery	✓	✓	✓	×	✓
Decontamnation in peri-implantitis	✓	×	✓	×	✓
Hyperkeratosis	✓	✓	✓	×	×
Precancerous lesions	✓	✓	✓	✓	×
Benign tumors	✓	✓	✓	✓	✓
Cysts in bone, cysts in soft tissues	✓	✓	✓	✓	✓
Scar corrections	✓	×	×	×	✓
Skin resurfacing	✓	×	×	×	✓

LASER IN IMPLANT DENTISTRY

Implant dentistry represents a viable alternative for many patients in need of a removable prosthesis. However, no one implant can accommodate all anatomic and prosthetic conditions.

When selecting an implant it should:

a. Integrate with biologic tissue
b. Have perimucosal fixtures that can pass through the soft tissue
c. Simulate near ideal periodontal health
d. All implants must pass through the submucosa and the covering stratified squamous epithelium into the oral cavity.

The gingival epithelium or biologic seal becomes an important factor in implant longevity. The seal must be effective enough to prevent the ingress of bacterial plaque, toxins, oral debris and other deleterious substances.

If a biological seal is created from the beginning of implant uncovering using laser technology versus conventional surgery, the attached gingiva would heal directly around the implant, forming an epithelial cuff.

Peri-implantitis

Peri-implantitis can create pockets around implants, so probing around the implants becomes part of the examination and diagnosis. To prevent scratching of the implant surface, plastic periodontal probes should be used instead of the usual steel probes used for the natural dentition.

Before any laser surgery is attempted, the initial surgery and healing process should be evaluated. A rigidly placed implant with no crestal bone loss and adequate zones of attached gingiva should be present. Soft tissue thickness of 1 to 3 mm with no tenderness or discomfort under vertical or lateral forces is needed.

Once the implant is uncovered with the laser under minimal anesthesia, the rigidity can be verified and most importantly any discomfort with lateral or vertical forces can be expressed verbally because only the soft tissue overlying the implant is anesthetized, soft tissue greater than 3 mm thick should be reduced with the laser to create an ideal pocket depth around the implant. If bone defects are encountered or the width of attached tissue is less than 3 mm full surgical reflection is recommended.

COSMETIC FACIAL LASER SURGERY

The laser is ideal for many cosmetic procedures because of its hemostasis, decreased scarring, improved control of depth and shortened period of disability after surgery. One of the more common procedures performed is cosmetic skin resurfacing.

This procedure treats facial lesions and skin wrinkles by removing the surface layer of the epidermis and superficial papillary dermis, contracting the dermal collagen and allowing the skin to re-epithelialize in a more uniform manner. The great advantage of the laser is that it can be controlled precisely to remove only the required layers of tissues by preserving the underlying structures that can provide epithelium and aid in internal healing of the wound postoperatively. The wound heals from inside-out rather than the much slower outside-in. Healing occurs rapidly, without scarring, even if the entire epidermis of the face is removed.

Some examples of cosmetic and facial dermatological uses of the laser includes epidermal nevi, tissue tags, lentigines, superficial pigmentation, seborrheic keratosis, skin wrinkles, blepharoplasty, scar revision, melasma.

The technical change that made cosmetic skin resurfacing possible was the incorporation of various ways to pulse a continuous wave of laser fast enough to limit the time for lateral spread.

Removal of surface tissue occurs with minimal thermal damage to the underlying structures.

Although CO_2 laser is most commonly used for this purpose, the Er: YAG is becoming popular as an alternative or in some cases, addition to the CO_2 laser, because it has even greater affinity for water absorption and pulsed Er: YAG results in less lateral thermal damage than a pulsed CO_2 laser.

Despite the dramatic nature of this surgery, the technique is merely a variant on the ablation or vaporization technique that is used intraorally.

LASER-ASSISTED ROUTINE CLINICAL PROCEDURES

Pericoronitis

Pericoronitis refers to inflammation of the gingiva in relation to the crown of an incompletely erupted tooth. It occurs most often in the mandibular third molar area. Pericoronitis may be acute, subacute, or chronic **(Fig. 11.4)**.

Clinical Features

The partially erupted or impacted mandibular third molar is the most common site of pericoronitis. The space between the crown of the tooth and the overlying gingival flap (operculum) is an ideal area for the accumulation of food debris and bacterial growth. Even in patients with no clinical signs or symptoms, the gingival flap is often chronically inflamed and infected and has varying degrees of ulceration along its inner surface. Acute inflammatory involvement is a constant possibility and may be exacerbated by trauma, occlusion, or a foreign body trapped underneath the tissue flap **(Figs 11.5A to D)**.

The resultant clinical picture is that of a red, swollen, suppurating lesion that is exquisitely tender, with radiating pains to the ear, throat, and floor of the mouth. The patient is extremely uncomfortable because of a foul taste and an inability to close the jaws, in addition to the pain. Swelling of the cheek in the region of the angle of the jaw and lymphadenitis are common findings. Trismus may also be a presenting complaint. The patient may also have systemic complications, such as fever, leukocytosis and malaise **(Fig. 11.6)**.

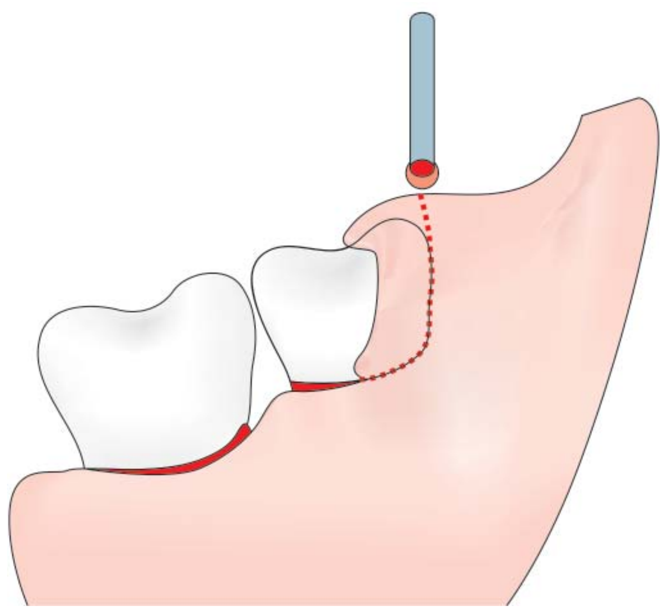


Fig. 11.4: Schematic representation of laser-assisted operculectomy. The pericoronal flap extends buccally and occlusally. The dotted line represents the line of excision

Fig. 11.5A: Preoperative photograph of pericoronitis

Fig. 11.5D: Patient recalled after 5 days

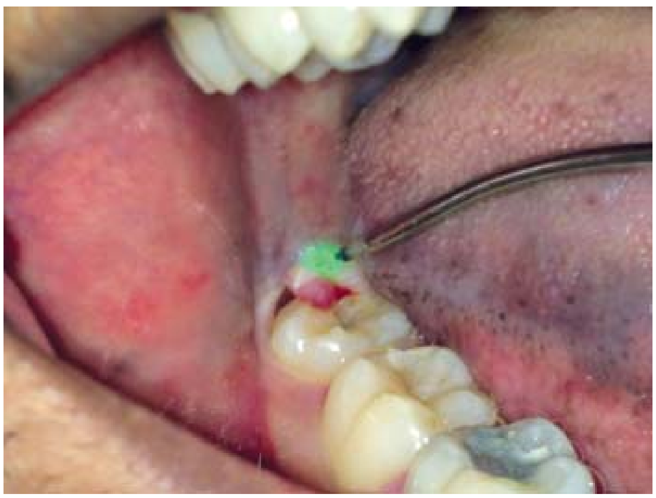


Fig. 11.5B: Pericoronal flap excised using Diode laser

Fig. 11.6: Example of a diode laser unit

Fig. 11.5C: Immediate postoperative view. There was no bleeding and no requirement of sutures

Frenectomy and Ankyloglossia

A *frenum* is a fold of mucous membrane, usually with enclosed muscle fibers, that attaches the lips and cheeks to the alveolar mucosa and/or gingiva and underlying periosteum. A frenum becomes a problem if the attachment is too close to the marginal gingiva. Tension on the frenum may pull the gingival margin away from the tooth. This condition may be conducive to plaque accumulation and inhibit proper toothbrushing.

Frenectomy is complete removal of the frenum, including its attachment to underlying bone, and may be required in the correction of an abnormal diastema. Both frenectomy and frenotomy are used to remove an abnormal frenal attachment, but frenotomy generally suffices for periodontal purposes, that is, relocating the frenal attachment so as to create a zone of attached gingiva between the gingival margin and the frenum **(Figs 11.7A and B)**.

Frenectomy and frenotomy are usually performed in conjunction with other periodontal treatment procedures but are done as separate operations. Frenal problems occur most often on the facial surface between the maxillary and mandibular central incisors and in the canine and premolar areas. They occur less often on the lingual surface of the mandible.

Clinical Application

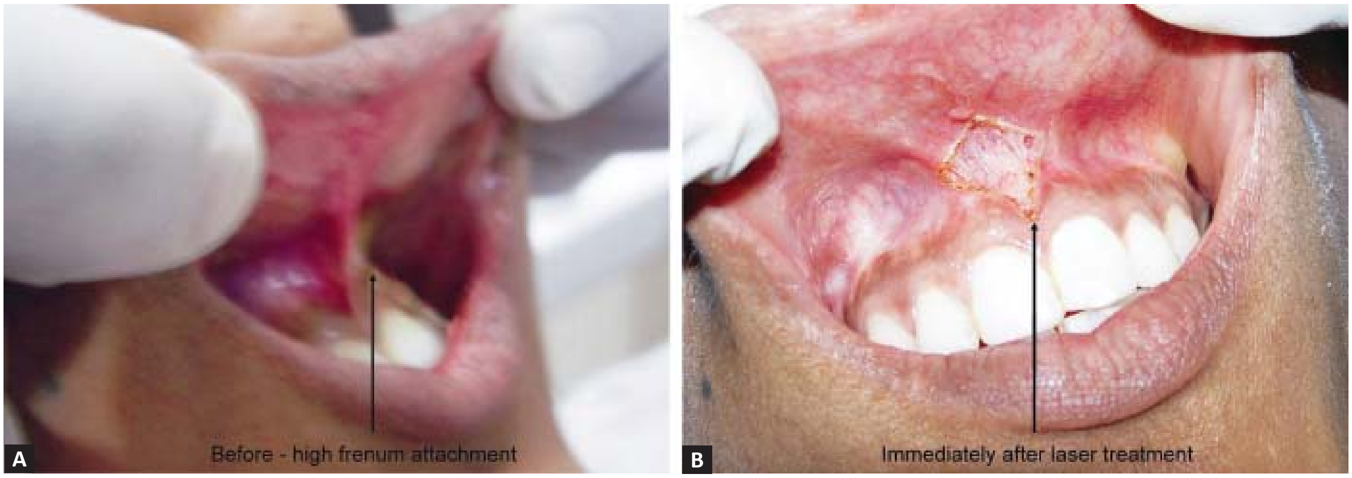
Although any laser can be used to successfully perform a frenectomy, achieving acceptable hemostasis is difficult when using Er lasers because of their free-running pulse and shallow tissue penetration. If Er lasers are used, the clinician can facilitate coagulation by using maximum hertz with no water spray.

Stabilization of the frenum during incision and ablation can be accomplished using an instrument such as a hemostat. In addition, the clinician can maintain tension on the frenal tissue by retracting the lip or tongue.

It is especially important to remove the full extent of the frenal attachment nearest to the teeth.

Lingual Frenectomy or Ankyloglossia

Lingual frenum is attached to the crest of the alveolar ridge and it connects to the tip of the tongue in edentulous patients. In dentulous patient, it is attached to the lingual gingiva, behind the mandibular incisors. This condition is known as tongue tie **(Figs 11.8A and B)**.



Figs 11.7A and B: Laser-assisted frenectomy using diode laser

Figs 11.8A and B: Laser-assisted lingual frenectomy using diode laser

Clinical Application

Studies report that ankyloglossia is relatively common in newborns and infants and can be manifested by problems with nursing and nutrition. Repositioning the lingual frenum increases the freedom of tongue movement and can alleviate nursing difficulty associated with ankyloglossia. When the frenectomy is performed, the infant is laid on the lap of the clinician or assistant. The infant's tongue is held by the clinician's fingers or retracted by a hemostat or grooved tongue positioner to stabilize the frenum. Local anesthesia is usually unnecessary. The procedure takes less than a minute and provides approximately 8 to 10 mm of increased tongue movement. As with all laser procedures, protective eyewear must be worn by the patient.

Vestibuloplasty

Labial Vestibuloplasty

The procedure is known *as transpositional flap vestibuloplasty or lip switch procedure,* when the soft tissues from the inner aspect of the lip is shifted to a favorable zone on the alveolar bone, so that the increase in the denture bearing area is achieved.

This method effectively increases the vestibular depth in the mandible, when the patient has a bone height of 15 mm or more in the anterior region. Implants or bone grafts should be considered in the patients having less than 15 mm of bone height in the anterior region. The mucosa must be healthy and exhibit no fibrosis, scarring or hyperplasia.

Lingual Vestibuloplasty

Floor of the mouth extension or floor of the mouth lowering:

Soft tissue attachments on the lingual aspect can interfere with prosthetic rehabilitation. Posteriorly the mylohyoid muscle and genioglossus muscle anteriorly, on the lingual surface of the mandible are the two problem areas.

1. Technique provides an adequate denture bearing area.
2. Eliminates the muscle attachments that dislodge the prosthesis.
3. Used in the mandible, when the mylohyoid and genioglossus attachments are close to the alveolar ridge.

Clinical Application

The laser incision is made at the junction of keratinized and nonkeratinized tissue. The surface of the nonkeratinized tissue is gently ablated, which allows for a new band of keratinized tissue to form as it heals. This procedure is much simpler than conventional techniques, such as palatal grafts. Any laser wavelength can be used to perform this procedure.

Recurrent Aphthous Ulcer Treatment

Laser treatment of recurrent aphthous ulcers can be performed with or without analgesia. Without analgesia, a defocused laser set to low power is placed between 6 and 8 cm from the ulcer and slowly circled in toward the lesion. If the patient begins to feel discomfort, the clinician slowly circles the laser 0.5 cm away from the lesion before slowly re-circling in toward the lesion. This process is repeated until the clinician can touch the laser to the lesion without patient discomfort. The lesion is "painted" with the laser fiber, making certain that the entire area of ulcerated mucosa is exposed to the laser energy. The lesion may bleed slightly, following which coagulate. Once the lesion has been completely covered by a film of coagulum, the treatment is completed **(Figs 11.9A to D)**.

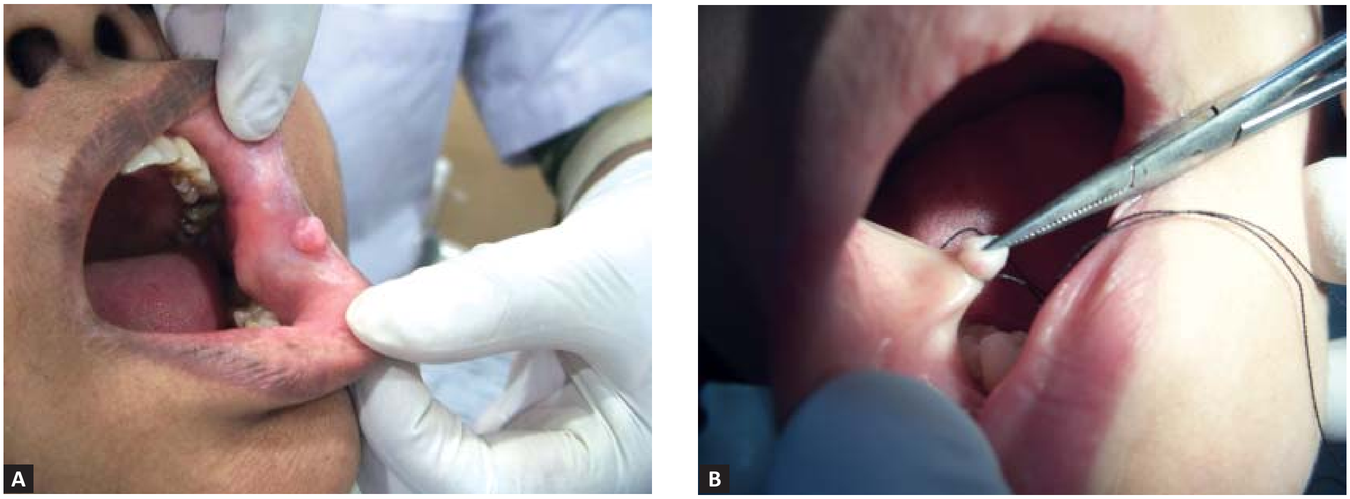
When using infiltration or topical analgesia, the clinician can immediately place the laser 1 mm from the lesion and "paint" the numb ulcerated area until the entire lesion has been covered.

Though most cases of this type may be treated without analgesia, the use of analgesia should be discussed with the patient before treatment is initiated.

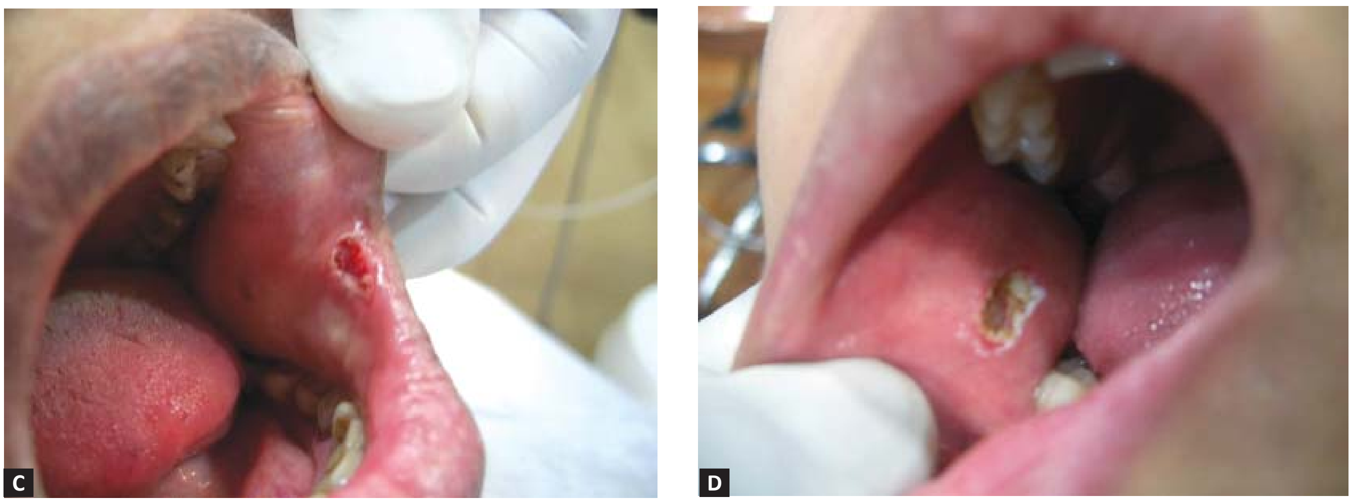
LASER-ASSISTED BIOPSY

Premalignant lesion is defined as "a morphologically altered tissue in which cancer is more likely to occur than in its apparently normal counterpart." Proper management of a patient with a premalignant or malignant oral lesion starts with an accurate diagnosis.

Diagnosis of oral lesions cannot be made solely on the basis of clinical examination, so histopathological diagnosis becomes mandatory for definitive diagnosis. Biopsy techniques like scalpel and punch are the conventional techniques used. Newer technique like CO_2 laser is gaining popularity.



Figs 11.9A and B: Photographs showing growth in the buccal mucosa



Figs 11.9C and D: Laser-assisted biopsy of the growth and complete excision

Biopsy is the removal of tissue from the living organism for the purposes of microscopic examination and diagnosis. The word biopsy originates from the Greek terms bios (life) and opsis (vision), meaning vision of life. A biopsy consists of obtaining a tissue from a living organism with the purpose of examining it under the microscope in order to establish a diagnosis based on the sample **(Figs 11.10A to C)**.

Clinically, low energy CO_2 lasers are useful in biopsies, soft tissue lesions, hemostasis, etc.

The aim and objective was to compare the efficiency of conventional scalpel (excisional/incisional) biopsy and newer technique like CO_2 laser.

In Conventional Scalpel Method an incisional biopsy was obtained and sutures were placed to achieve hemostasis. In laser biopsy it is initially placed in a cutting or focused mode, held perpendicular to the tissue, and follows the predefined surgical outline. By means of a tissue pickup, a border of the outline is raised and the lesion is undermined with traction-counter traction, as would be done with scalpel **(Figs 11.11A to C)**.

Power setting may vary depending on the laser used and the skill of the operator, on average, power setting is in a range from 4W to 6W. Once the lesion has been removed, the area is left to heal by granulation and it is noted after two days and also after two weeks.

Lasers biopsy showed healing by granulation tissue formation whereas scalpel biopsy showed contraction of the wound due to placement of sutures.

Fig. 11.10A: Mucocele in relation to the lower lip

Fig. 11.10B: Immediate postoperative photograph following excision using Nd:YAG laser

Fig. 11.10C: One-week healing

Figs 11.10A to C: *Case courtesy: Dr Anita Nitin, Vikram Perfect, Mysore, Karnataka, India*

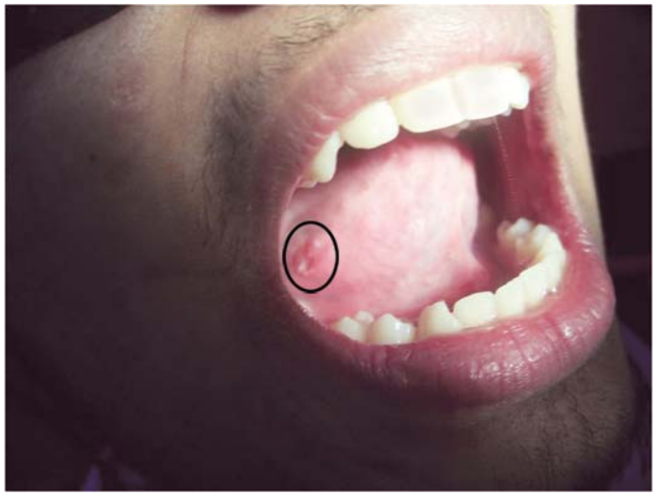


Fig. 11.11A: Patient came with a complaint of ulcer on the tongue. Encircled area shows the ulcer lesion

Fig. 11.11B: Laser-assisted excision of the ulcer

Fig. 11.11C: Postoperative view of the ulcer after one week

Conclusion

The early detection of potentially malignant tissue change may reduce morbidity and mortality from oral cancer. Biopsy has always been the gold standard in diagnosis and should be utilized when patients present with suspicious lesions. A multi-disciplinary approach should always be considered for the treatment of these patients.

The pain and postoperative swelling usually observed after scalpel are minimally seen after the procedure has been conducted with lasers.

Types of lasers employed in biopsies are: (1) The Neodymium Laser (Nd:YAG) (2) The Ruby Lasers (3) The carbon dioxide laser. Carbon dioxide lasers became more popular in dental practice.

Healing is rapid as bleeding at the site is less as compared to scalpel biopsy but re-epithelialization takes longer time.

The usage of lasers requires the presence of specific technicians, laser specific education and clinicians trained adequately for the same. Laser specific standards are to be followed and the loss of tactile sensation reduces the judgment for the surgeon, especially in controlling the depth of the biopsy.

The CO_2 laser is a precise means of eliminating soft tissue pathosis and can be used to excise benign, premalignant, and malignant lesions in the mouth.

Also, with the availability of portable and cost effective lasers in the market, exploring this newer technique appears to be a preferable option **(Figs 11.12A to F)**.

Fig. 11.12A: Intraoral view of impacted 38

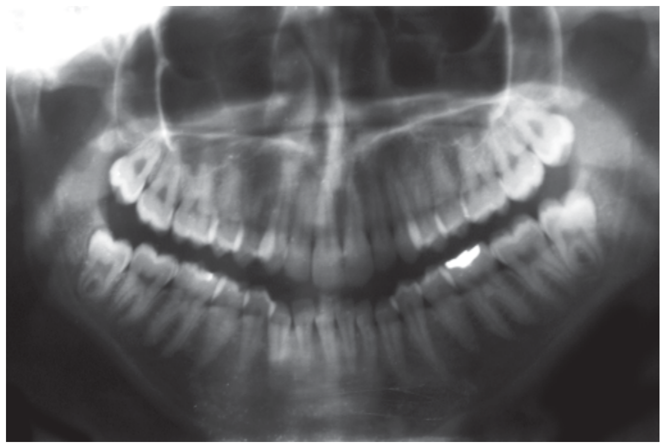


Fig. 11.12B: OPG showing bony impaction of 38

Fig. 11.12C: Reflection of the flap to expose the bone. Nd:YAG laser for gingival cutting – 50 hz 4 watt, 300 micron fiber

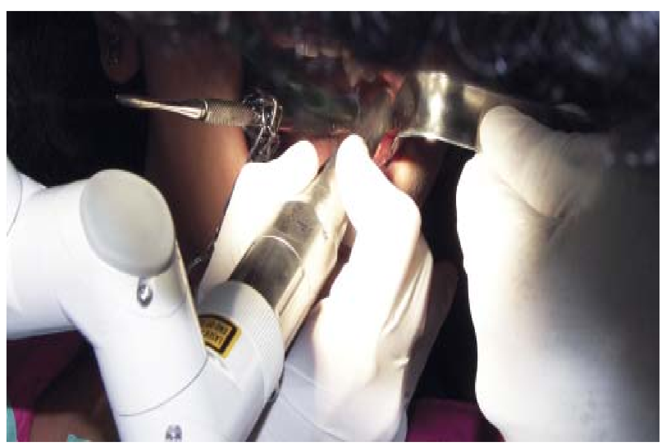


Fig. 11.12D: Er:YAG laser for bone cutting, contact R14 handpiece, SSP 200-300 mJ, 20 Hz, water spray

Fig. 11.12E: Luxation of the tooth after bone cutting

Fig. 11.12F: Surgical site post-extraction of 38

Figs 11.12A to F: *Case courtesy: Dr Anita Nitin, Vikram Perfect, Mysore, Karnataka, India*

SUMMARY

Because of their many advantages, lasers have become indispensable in OMFS as a modality for soft tissue surgery. Lasers not only enhances the current surgical options for treatment, but also have expanded the scope of practice.

Laser used in implant dentistry provides a most controlled environment at the operative site. Control is a pre-requisite for successful prosthetics and is accomplished by unique ability of the laser to interact photothermally with biologic tissues using the lightest touch.

Hemostasis is the result of this interaction by coagulating and sealing small blood and lymph vessels and vaporizing soft tissue.

Use of dental laser technology provides the advanced laser and reconstructive dentist with the tool to improve the scope of his surgical practice.

CHAPTER 12

LASER AS AN ADJUNCT TO ORTHODONTICS

- Introduction
- Laser-assisted Bonding
- Laser-assisted Tooth Exposure

INTRODUCTION

Orthodontics is no longer limited to aligned teeth and perfect occlusion. The resignation to long duration of the treatment and frequent appointments has been replaced by the demand for shorter treatment duration with superior esthetic and functional results. An orthodontist must therefore, fashion the treatment plan in such a way that he can achieve the best possible dental and facial relation along with optimal soft tissue contours.

LASER-ASSISTED BONDING

Frequent bracket de-bonding increase treatment time, nonextraction treatment is shorter and the newer self-ligating brackets decrease chairside time and also the over-all treatment time. Since only those teeth can be moved on which orthodontic brackets are bonded, it is pertinent to involve the erupting and the impacted teeth as early as possible into the orthodontic appliance. The brackets are placed in the middle third of the clinical crown. An accurately placed bracket prevents 'round tipping' and facilitates speedy completion of the treatment. An obstructed crown, wherein the dentist is forced to wait of the tooth to erupt causes undue delay in the treatment. This is where soft tissue lasers play an important role **(Figs 12.1A to C)**.

LASER-ASSISTED TOOTH EXPOSURE

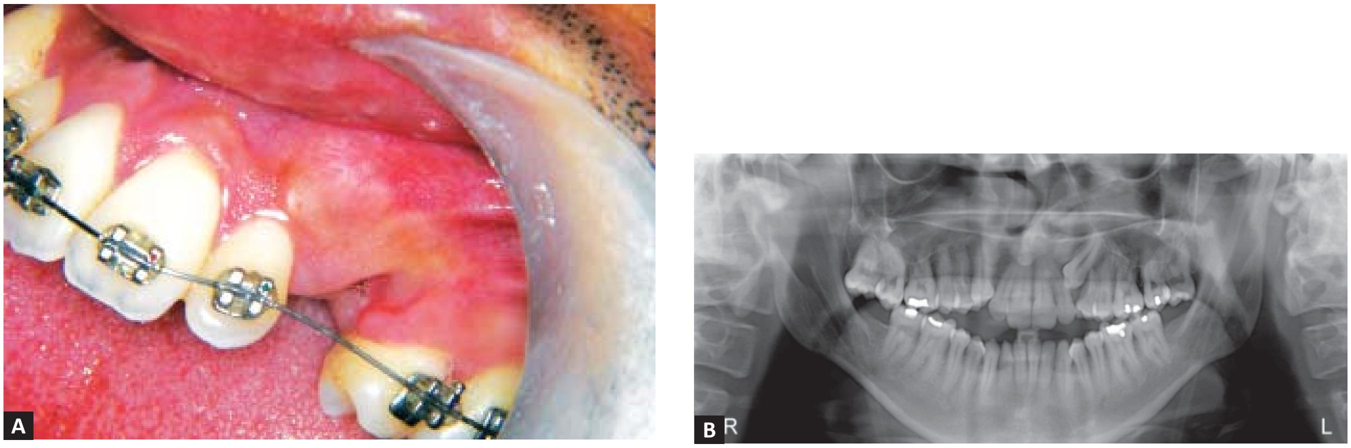
Impacted or partially erupted teeth, where bracket bonding and positioning are a challenge due to limited moisture control and the available tooth structure for bonding prolong orthodontic treatment and exposure of such teeth using conventional means is associated with the use of local anesthetics and blood. Such procedures not only decrease patient acceptance but also lead to frequent bracket de-bonding and an increased treatment time. These problems can be easily overcome with the use of soft tissue lasers for exposing the impacted teeth and increasing the clinical crown length of such teeth. The procedures are painless and bloodless which in turn increases patient acceptability and the operator efficiency, the predictability of the treatment, decreases the chairside time and the overall treatment time **(Figs 12.2A to G)**.

Fig. 12.1A: Photograph showing upper arch prior to placement of brackets

Fig. 12.1B: Laser-assisted etching. Laser type:
Er: YAG (Hard tissue- enamel)
Setting: VSP 10 Hz, R02 non-contact handpiece, <150 mJ

Fig. 12.1C: Bonding of fixed orthodontic appliance

Figs 12.1A to C: *Case courtesy: Dr Anita Nitin and Dr Anil SR, Vikram Perfect, Mysore , Karnataka, India*



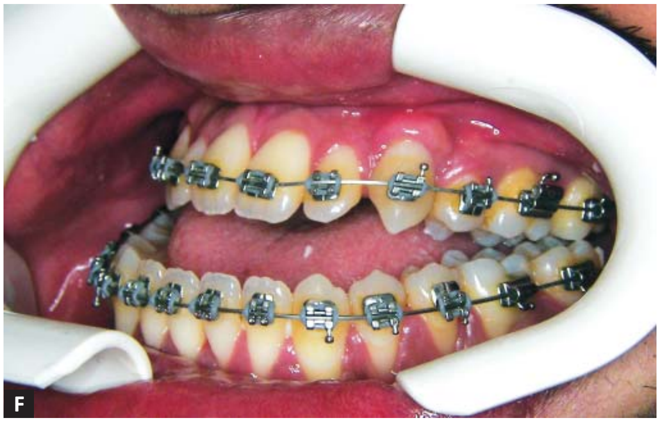
Figs 12.2A and B: (A) Intraoral and (B) radiographic view of impacted canine respectively

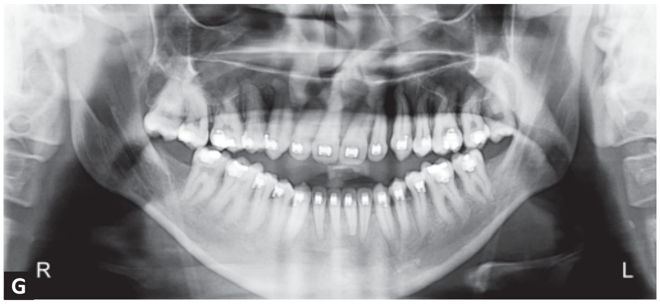
Fig. 12.2C: Laser-assisted tooth exposure. Laser type: Nd:YAG (soft tissue)

Setting: 4 watts and 50 Hz

Fig. 12.2D: Immediate postoperative view

Fig. 12.2E: Extrusion of the canine





Figs 12.2F and G: (F) Intraoral and (G) radiographic view of the canine after complete alignment respectively

Figs 12.2A to G: *Case courtesy: Dr Anita Nitin and Dr Anil SR, Vikram Perfect, Mysore, Karnataka, India*

Fig. 12.3A: Photograph showing midline diastema caused by high frenal attachment

Fig. 12.3B: Immediate postoperative view of laser-assisted frenectomy. Laser type: Nd: YAG (soft tissue)

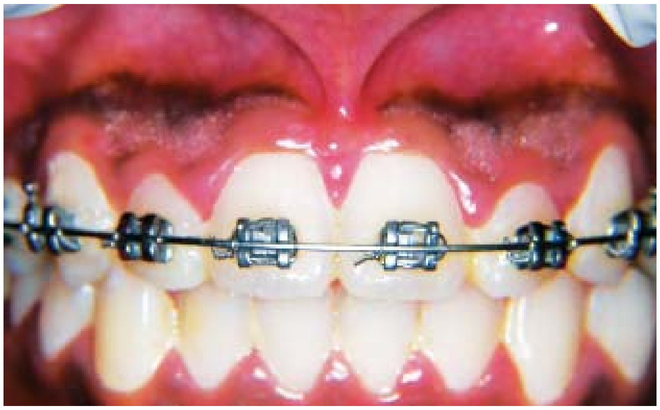


Fig. 12.3C: Photograph showing the level of attachment of the frenum after healing

Fig. 12.3D: Closure of the diastema with orthodontic appliance

Figs 12.3A to D: *Case courtesy: Dr Anita Nitin and Dr Anil SR, Vikram Perfect, Mysore, Karnataka, India*

These lasers are capable of exposing the erupting teeth bloodlessly and rather painlessly without the use of the painful and at times fearful injections and provide the right amount of hemostasis; thus, enabling immediate bonding and wire ligations (**Figs 12.3A to D**).

CONCLUSION

A decrease in orthodontic treatment time is not only a demand by the esthetically concerned patient but is also the duty of every orthodontist. Maintaining good oral hygiene along with fixed appliances is always cumbersome. The teeth to be moved need to be incorporated within the appliance as early as possible so as to move them in the desired direction. Unfortunately, sometimes the orthodontist is forced to follow the wait and watch policy if the patient is hesitant to undertake the exposure of such teeth by conventional means under local anesthesia. Even if the patient agrees, hemostasis and bonding in a wet environment remains an issue. Under the best of isolation the rate of bracket bond failure on such teeth remains high.

The advent of soft-tissue lasers provides a convenient and effective way for the orthodontist to achieve tooth exposure without the use of fearful needles as well as achieving a near bloodless field. A bloodless field ensures proper isolation and hence, proper bond strength. This in turn minimizes bracket bond failures and indirectly leads to shorter treatment time as well as decreased chair-side time.

The various uses of soft tissue lasers in orthodontics are indicated. The added advantage of biostimulation when studied in detail, as an aid to increasing the rate of tooth movement might be yet another use that can be explored. In addition a better gingival health and contour with minimal scarring and various other advantages over conventional scalpel surgery cannot be overlooked and need to be incorporated into the day to day practice of orthodontics for the overall benefit of the patient.

13

CHAPTER

Low Level Laser Therapy

- Introduction
- Mechanism of Action
- Cellular Effects of LLLT during Wound Healing
- Effect of LLLT on Neural Tissues
- LLLT Applications in Clinical Dentistry
- LLLT Equipment
- Advantages and Disadvantages of LLLT

INTRODUCTION

Low level laser therapy (LLLT) is also known as 'soft laser therapy'. It is based on the concept that certain low level doses of specific coherent wavelengths can turn on or turn off certain cellular components or functions. Administering LLLT to patients helps in healing, reducing pain, swelling and controlling oral infections.

The lasers that are used most commonly are the helium neon (633 nm) or diode (820 or 904 nm) with power outputs much below 1W. The wavelengths used for LLLT have poor absorption in water and thus penetrate soft and hard tissues from 3 mm upto 15 mm. Thermal effects of LLLT on dental tissues are not significant. As the energy penetrates tissue, there is multiple scattering by both microvessels and erythrocytes. The distribution of microvessels in the tissue influences the final distribution pattern of laser energy.

MECHANISM OF ACTION

The mechanism of LLLT depends upon the absorption of particular visible red and near-infrared wavelengths in photoreceptors within subcellular components, particularly the electron transport chain within the membranes of mitochondria. The absorption of light by the respiratory chain components causes a short-term activation of the respiratory chain and oxidation of the NADH pool.

This stimulation of oxidative phosphorylation leads to changes in the redox status of both the mitochondria and cytoplasm of the cell.

The electron transport chain is able to provide increased levels of promotive force to the cell, through increased supply of ATP, as well as an increase in the electrical potential of the mitochondrial membrane, alkalization of the cytoplasm and activation of nucleic acid synthesis. Because ATP is the "Energy currency" for a cell LLLT has a potent action that results in stimulation of normal functions of the cell.

Irradiation with monochromatic visible light in the blue, red and far red regions can enhance metabolic processes in the cell. The photobiological effects of stimulation depend on the wavelengths and intensity of the light.

By increasing the respiratory metabolism of the cell, LLLT can also affect the electrophysiological properties of the cell.

CELLULAR EFFECTS OF LLLT DURING WOUND HEALING

The two effects of LLLT that contribute to accelerate healing are:

- Vasodilation
- Relaxation of smooth muscles.

The vasodilative effect causes increased local blood flow and is used in the treatment of joint inflammation.

It causes the relaxation of smooth muscles associated with endothelium. This vasodilation brings in oxygen and also allows for greater migration of immune cells into tissue.

It can also exert vaso active effects by its action on mast cells. Mast cells play a pivotal role in controlling leukocyte migration. Modulation of mast cell functions by LLLT can be of considerable importance in the treatment of sites of inflammation in the oral cavity.

The laser light can trigger mast cell degranulation. Mast cells are distributed over the microvascular endothelium in skin, oral mucosa and dental pulp. Mast cells in these locations contain the proinflammatory cytokine tumor necrosis factor - α in their granules. Release of this cytokine promotes leukocyte infiltration of tissues by enhancing expression of endothelial leukocyte adhesion molecules.

Possible mechanisms involved in the acceleration of wound healing by LLLT described in the **Table 13.1**.

Early epithelization, increased fibroblastic reactions, leukocyte infiltration and neovascularization are seen in wounds irradiated using LLLT. Because of overall impact of these influences, the time required for complete wound closure is reduced.

Biomechanical and biochemical results suggest that laser photostimulation promotes the tissue repair process by accelerating collagen production and promoting overall connective tissue stability.

The final effect of LLLT on cells relates to the effects of laser light on the cytoskeleton. It can modulate cell behavior by causing re-arrangements of the cytoskeleton.

Table 13.1

Possible mechanisms involved in the acceleration of wound healing by LLLT					
Fibroblasts	**Macrophages**	**Lymphocytes**	**Epithelial cells**	**Endothelium**	**Neural tissue**
Proliferation	Phagocytosis	Activation	Molility	Increased granulation tissue	Reduced synthesis of inflammatory mediators
Maturation	Secretion of fibroblast growth factors	Enhanced Proliferation		Relaxation of vascular smooth muscle	Maturation and regeneration
Locomotion	Fibrin resorption				Axonal growth
Transformation into myofibroblasts					
Reduced secretion of PG E_2 and 1L-1					
Enhanced secretion of bFGF					

It causes stimulation of connective tissue cells that results in the differentiation of myofibroblasts which are mainly responsible for the contraction force during wound healing. Myofibroblasts show morphologic features in common with fibroblasts and smooth muscle cells.

Laser treatment shortens the exudation phase of wound healing in skin and stimulates the reparative process. LLLT showed the greatest wound area reduction between 1 and 3 days after treatment. Faster wound closure is of great importance in compromised patients, such as diabetics and patients undergoing treatment for malignancies. Because LLLT can enhance the release of growth factors from fibroblast and can stimulate cell proliferation, it is able to improve wound healing in such compromised patients.

EFFECT OF LLLT ON NEURAL TISSUES

Following LLLT, neural tissues show reduced synthesis of inflammatory mediators, as well as more rapid maturation and regeneration, particularly axonal growth. LLLT also reduces pain in patients suffering from post-herpetic neuralgia, from cervical dentinal hypersensitivity or from periodontal pain during orthodontic tooth movement.

It may also be beneficial in treating TMJ disorders. LLLT used on patients with injuries to joints in other locations (ankle, knee, shoulder and wrist) using either the AlGaAs (λ = 830 nm) diode laser in continuous wave mode or the He-Ne laser combined with diode laser in pulsed mode, have shown benefits in reduction in pain and swelling. Patients treated with LLLT obtain pain relief and recover function more rapidly compared to untreated patients. LLLT is used in the dental office to treat disorders including TMJ, trigeminal neuralgia and muscular pain. The effects are mediated by a combination of both local and systemic effects.

LLLT has proven to be very effective when applied to "Trigger points", i.e. myofacial zones of particular sensibility and of highest projection of focal pain points, due to ischemic conditions.

An additional benefit is the use of LLLT to achieve an analgesic effect in the dental pulp prior to restorative procedures. When operated at pulse rates between 15 and 20 Hz, at pulse energies below the ablation threshold of tooth structure, the erbium laser energy penetrates into the tooth and is directed along hydroxyapaftite crystals towards the dental pulp. LLLT cause a disruption in the action of the Na – K pump in the cell membrane, resulting in a loss of impulse conduction and thus an analgesic effect. The duration of this effect is ~15 min.

There are parallels of the dental laser analgesic effect with several simulations in medicine in which simultaneous nondestructive thermal and nonthermal bioactivation occur at the periphery of the target tissue. This phenomenon of "simultaneous LLLT" also may occur along with the high level laser treatment.

The LLLT decreases the firing frequency of nociceptors, with a threshold effect required to exert maximal suppression. It results in the analgesic effect of LLLT on nerves supplying the oral cavity **(Fig. 13.1)**.

LLLT APPLICATIONS IN CLINICAL DENTISTRY

Lower level laser applications in dentistry include the promotion of wound healing in a range of sites, including:

- Surgical wounds to oral soft tissues
- Gingival incisions
- Extraction sites (bone fill and soft tissue healing)
- TMJ injury or arthritic disease
- Neuronal tissue which has been injured or transected, to accelerate regeneration

Fig. 13.1: Terra Quant solo soft laser

Table 13.2

Principles of therapy
– Regulatory effect: LLLT acts as a trigger for the endogenous, restitution of proper function
– Selectivity
– Biologic effects: Individual differences in biological effects
– Necessary energy density

- Lesions of recurrent aphthous stomatitis
- Oral ulceration (mucositis) induced by cancer chemotherapy **(Table 13.2)**.

Indications

Traumatological and postoperative conditions

Infracture	Wound healing complication
Contusion	Postimplantation
Hematoma	
Superficial anesthesia	
Postextraction	

Diseases of the jaw joint

Trismus	Arthrosis temperomandibularis
Hemarthos	Arthrogenous pain
Hydarthos	Myogenous pain

Diseases of the nerval structures

Dentalgia
Trigeminal neuralgia
Iatrogenic neuralgia
Tumor neuralgia

Soft tissue lesions

a. Inflammatory diseases such as:
   Abscess, gingivitis, periodontitis, pericoronitis, alveolitis, pulpitis, granuloma, aphthous
b. Infectious diseases such as:
   Herpes labialis, candidosis, stomatitis aphthosa.

Other dental indications

- Bone regeneration
- Orthodontic treatment to accelerate alveolar bone remodelling
- Wound healing: Postoperative regenerations takes place in 3 phases: Inflammatory phase, proliferative phase and tissue reconstruction phase
- Tooth hypersensitivity: Change of neuronal transmission
- Peri-implantitis, periodontitis **(Table 13.3)**.

Table 13.3

Dosage principles
Minimal response dose
Time of irradiation / cm$_2$ 30 sec–3-4 min
Power density: 1 mW / cm^2 – 100mW / cm^2
Wavelength: 632 – 904 nm

Factors Affecting the Efficacy of LLLT

1. **Patient selection factors** such as use of anesthesia, length of follow up, inclusion of controls, standardized clinical presentation, optimal 'window' for the timing of treatment.
2. **Optical factors** such as wavelength, spot size, laser or LED light source, power density, energy density, mode of operation, timing of treatment **(Table 13.4)**.

LLLT EQUIPMENT

Semiconductor diode laser are compact and have a high conversion efficiency from electrical energy to laser energy. It is also possible to pulse the light at various frequencies using simple external circuitry.

Semiconductor diode lasers are generally variants of either aluminium: gallium: arsenide (Al Ga As) or indium: gallium: arsenide: phosphorus (In GA ASP) which emit in the near infrared spectrum (λ = 700 to λ = 940 nm) and in the red portion of the visible spectrum range (wavelength λ = 600 to 680 nm) respectively. Power outputs are typically of the order of 10-50 mW. The final usable output will be less because of losses in the internal optical path or in the delivery system.

The temperature or output of the laser diode is monitored by using an internal phototransistor which is fitted within the package of the laser device. With an adequate heat sink and cooling system, the potential negative effect of temperature on laser output at the level of the treatment beam can be eliminated.

The beam profile from a typical diode laser is rectangular, with a high divergence on the long axis and a low divergence on the short axis. This gives a highly divergent oval or 'sweep' profile. Diode laser may have integrated optics which produce collimated and focused light beams.

To obtain a more useful beam, a series of lenses or a self focusing graded index fiber can be used in the front of the device to either deliver the treatment beam itself or to direct the laser output into a small diameter flexible optical fiber or a solid light guide.

Table 13.4

Soft laser effects
Wound healing
Anti-edemic effect
Analgesic effect
Tissue reparative effect
Bone regeneration
Nerve fiber regeneration

The components which come into direct contact with patients should be able to be protected adequately with a laser transmissive disposable barrier.

Laser units used for LLLT are generally classified as class III or class III b in terms of the optical hazards they pose to staff and patients. It is mandatory to wear appropriate protective glasses by patients and clinicians during treatment.

LLLT Devices

Q-1000 Soft Laser

The Q-1000 has been clinically tested and is used worldwide by healthcare professionals in the fields of physical therapy, rehabilitation, dental health and sports medicine. It is portable low level laser device on the market that uses a unique combination of pulsed laser light and infrared radiation to deliver consistent, controlled results. Low level laser therapy may be used any place there is acute or chronic pain or inflammation, and, low level laser therapy may be effective on any disease or disorder **(Figs 13.2A and B)**.

Specific uses include:
- Acupuncture
- Facial and skin treatment
- Dental
- Physical therapy
- Anti-aging medicine.

LaserHeal LH302:

LaserHeal is soft laser therapy unit used for treatments in:
- Physical and sports medicine
- Dentistry
- Gynecology
- Acupuncture.

This laser has a power ranging from 50-700 mW and wavelength 600-900 nm.

LC KMI Unique Type

Source of lasers: HeNe laser 632 nm 15 mW in head as standard unit, Optional FIR heater (far infrared) 300 W or Blue light.

Fig. 13.2A: Q-1000 soft laser

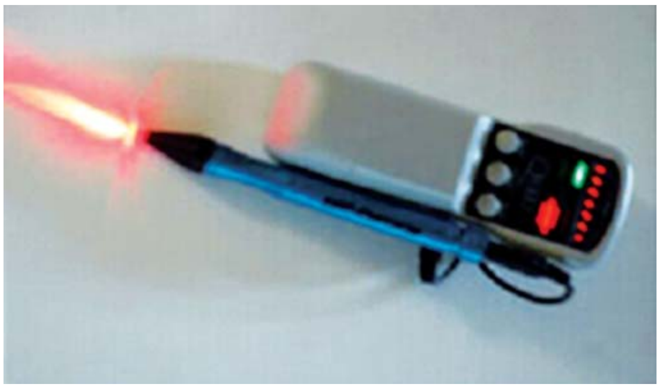


Fig. 13.2B: Q-600 enhancer probe

Applications: Antalgic therapy, rheumatology, physiotherapy, sports medicine, orthopedic, traumatology, geriatrics, dermatology (acne, herpes, burn, ulcer), ENT, dental, etc.

LC KMI DY Type

Source of lasers: HeNe laser 632 nm 15 mW in head as standard unit. Blue light lamp 407~420 nm.

ADVANTAGES AND DISADVANTAGES OF LLLT

Advantages of Low Level Laser Therapy

- Power of laser can be controlled and mode sight and period of application can be selected
- No touch performance hence aseptic atraumatic
- Rapid painless and accurate application
- Short treatment period
- Analgesic, antiphlogistic and wound healing stimulatory effect occurs simultaneously
- Broad spectrum of indications.

Disadvantages of Soft Laser Therapy

- Occasionally, separate devices are required in getting the beam onto area to be treated
- The therapeutic effects is often hard to control by objective parameters.

SUMMARY

LLLT has been found to accelerate wound healing and reduce pain, possibly by stimulating oxidative phosphorylation in mitochondria and modulating inflammatory responses. By influencing the biologic function of a variety of cell types, it is able to exert a range of several beneficial effects upon inflammation and healing LLLT exerts marked effects upon cells in all phases of wound healing, particularly during the proliferative phase.

The enhanced cell metabolic functions seen after LLLT are the result of activation of photoreceptors within the electron transport chain of mitochondria.

CHAPTER

14

Photo-Activated Disinfection

- Introduction
- Photo-dynamic Therapy (PDT)
- Photosensitizers
- Indications of PAD Technique
- Lasers Used in PAD

INTRODUCTION

Photo-activated disinfection (PAD) is defined as "a method of disinfecting or sterilizing a hard tissue or soft tissue site by topically applying a photosensitizing compound to the site, and then irradiating this with laser light at a wavelength absorbed by the photosensitizing compound, so as to destroy microbes at the site."

The key principle is that the laser activated agents must bind selectively to the target cells rather than to adjacent normal human cells. The photosensitizing compound, when irradiated, releases cytotoxic compounds, particularly singlet oxygen. The applications of photo-activated disinfection in dentistry and medicine are wide and include the destruction of bacterial, fungal and viral pathogens.

PAD may represent a viable alternative to antibiotics and antiseptics for the treatment of localized infections, particularly for those caused by organisms which are innately resistant or have developed resistance to conventional antimicrobial agents. The oral cavity is particularly suitable site for this treatment.

PHOTODYNAMIC THERAPY (PDT)

In photodynamic therapy, laser activation of a sensitizing dye generates reactive oxygen species (ROS), which directly damage cells and the associated blood vascular network, triggering both necrosis and apoptosis. It also alters the host anti-tumor immune response.

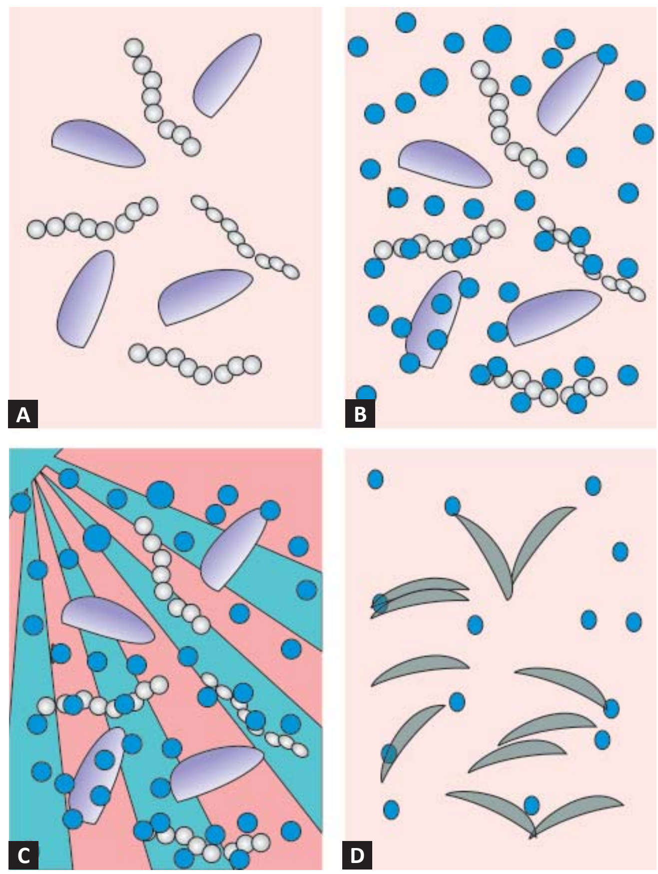
When used for oral mucosal malignancies such as squamous cell carcinoma and carcinoma *in situ*, PDT has a response rate of ~90%. The treated sites show erythema and edema, followed by necrosis and frank ulceration. The ulcerated lesions take upto 8 weeks to heal fully and supportive analgesia is required in the first few weeks.

PDT is less destructive to normal tissues than the conventional treatments of surgery or radiotherapy.

Mechanism of Action of PAD

It is based on the interaction of a photosensitive antimicrobial agent and a source of light. When the photosensitizing agent is exposed to the light source of a particular wavelength, it absorbs photons of energy with subsequent transition to the next state—singlet excited state. From here, the electrons may fall back to the ground state and release the gained energy via electronic or physical processes (fluorescence), or they may jump to the next excited state (intersystem cross over) the triplet excited state.

Whether the molecule follows the first or the second path is determined by its molecular structure and also by its surrounding environment **(Figs 14.1A to D and Flow chart 14.1)**.



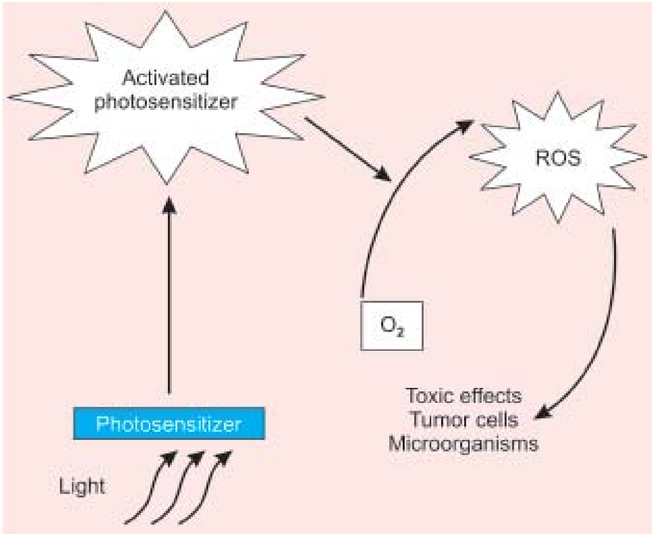
Figs 14.1A to D: (A) Mixed gram +ve and gram –ve bacterial infection, (B) PAD solution tags all bacteria, (C) Solution activated by laser resulting in the release of singlet oxygen, (D) Elimination of bacteria

Once in the triplet excited state, the molecule may fall back to the ground state or undergo reactions with molecular oxygen, transferring its energy to the molecule.

Reactions that take place with oxygen are of two types:

1. Those that give rise to hydroxyl radicals, superoxide ions, peroxides and radicals which then instigate redox reactions with the surrounding environment, and
2. Those that result in the formation of a labile singlet oxygen or reactive oxygen species.

Flow chart 14.1: Flow chart showing the mechanism of action of laser on bacteria



The formation of labile singlet oxygen and the evoked cascade of redox reactions are the primary mechanisms that destroy bacterial cells and their cellular components.

Bacterial killing is achieved by determining how many triplet state molecules are generated from the photo sensitizers and this in turn is determined by how long it can stay in the triple excited state.

PHOTOSENSITIZERS

A limited number of bacteria naturally produce endogenous photosensitive agents and therefore can be killed by exposure to laser light alone of the proper wavelength.

There are many types of photosensitizers, both naturally occurring and synthetically produced **(Table 14.1)**.

Table 14.1

Common Photosensitizer/laser combinations
– Tolonium Chloride with a 635-nm diode laser or a 632.8-nm helium-neon gas laser
– Methylene blue with a 670-nm diode laser
– Aluminum disulfonated phthalocyanine with a 660-nm diode laser

Photosensitizers used in PAD: Tolonium chloride, methylene blue, crystal violet azure dyes, hematoporphyrins, chlorins.

To achieve optimal results with PAD therapy, the photosensitizers should possess the following characteristics:

- The cell types to which the photosensitizer binds
- The concentrations at which its actions are most effective
- The wavelength of light required to activate it and the intensity of this light
- The concentration at which it would exhibit any toxic effects and what these would be
- Its solubility in water and lipid environments
- Its degree of ionization
- The excitation efficiency and how long it can stay in the triplet state.

INDICATIONS OF PAD TECHNIQUE

- Disinfecting carious dentine prior to restoration
- Treating periodontal pockets
- Treating plaque infected cervical regions of teeth and dental implants
- Destroying carcinogenic microbes on a tooth surface in order to treat or prevent dental caries
- Disinfecting oral tissues prior to or during surgical procedures
- Treating oral candidiasis in immune compromised patients
- Treating denture stomatitis.

The presence of organic materials (such as blood and saliva) may offer some protection to bacteria against lethal photosensitization. Decreased effectiveness in the presence of serum and saliva is due to several factors.

- Partial absorption of laser light, which reduces the yield of cytotoxic molecules produced from the dye
- Electrostatic interaction with the dye, thus decreasing the number of photosensitizer molecules available for binding to the target bacteria
- The presence of scavenger molecules such as catalase and lactoperoxidase and direct protection from singlet oxygen.

Typical microbes killed by PAD are described in **Table 14.2**.

LASERS USED IN PAD

The laser types most commonly used in PAD operate in the red visible portion of the electromagnetic spectrum.

It includes AlGaAs (λ = 660 ≃ 670 nm) and helium–neon gas lasers (λ = 632.8 nm). PAD laser system with diode lasers employ a solid state peltier cooling device, which is attached directly to the rear surface of the diode laser **(Figs 14.2A to E)**.

Table 14.2

Typical microbes killed by PAD
Streptococcus sanguis
Streptococcus mutans
Streptococcus sobrinus
Lactobacillus fermentun
Actinomyces viscosus
Porphyromonas gingivalis
Fusobacteriun nucleatum
Actinobacillus actinomycetemcomitans
Staphylococcus aureus
Escherichia coli

Typical PAD parameter for effective killing of microbes are of order 15 J/cm^2, delivered using a laser with an output power of upto 100 mW. Range of delivery systems include simple optical fibers with cloven ends, to more complex photodynamic therapy diffusers with spherical or cylindrical emission patterns for use in carious lesions and root canals respectively.

The use of diffuser tip ensures an even irradiation of the target site. The diffusion effect reduces the effective power density and this reduces the risk for optical injury from the laser **(Fig. 14.3)**.

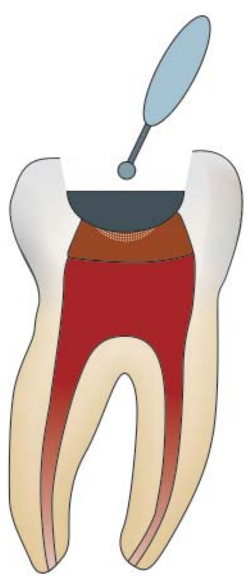


Fig. 14.2A: Removal of undermined enamel to access the carious lesion

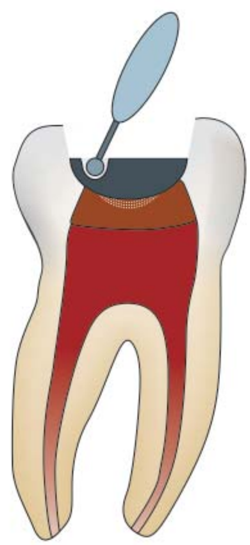


Fig. 14.2b: Excavation of carious lesion and cavity preparation

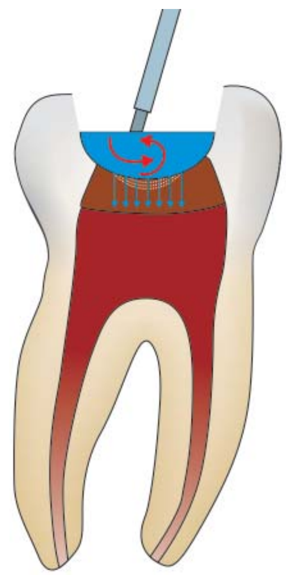


Fig. 14.2C: Application of tolonium chloride solution

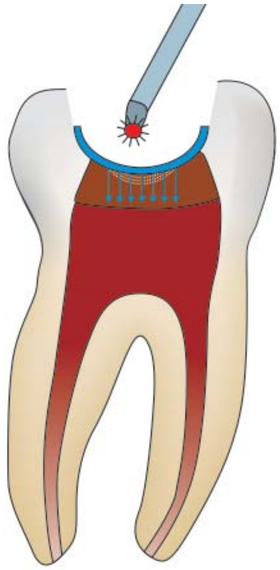


Fig. 14.2D: Activation of laser light for 60 secs to disinfect the remaining lesion

Fig. 14.3: Example of aseptium unit

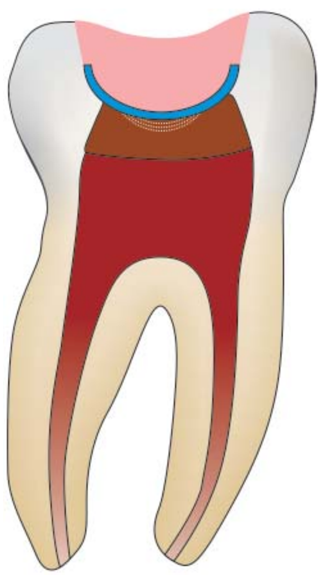


Fig. 14.2E: Restoration following disinfection

SUMMARY

PAD is an improved form of LLLT in which the laser energy in itself is not particularly lethal to bacteria, but is used to achieve photochemical activation of oxygen – releasing dyes. Tolonium chloride is the preferred dye as it gives the most consistent bactericidal effect across a range of bacterial species of importance to dentistry.

The effectiveness of PAD is influenced by the type and concentration of dye, the laser parameters employed and the local growth environment. PAD treatment does not induce deleterious thermal effects and does not injure adjacent tissues by thermal or chemical effects. Therefore, PAD is a valuable component in the modern practice of laser dentistry.

Major applications of PAD include the disinfection of deep carious lesions, periodontal pockets and peri – implant sites, mucosal wounds and root canals.

CHAPTER

15

Integrating Lasers into your Practice: Practice Management

- Introduction
- Dental Office in 21st Century
- Establishing Fees for Laser Procedures
- Marketing Laser Dentistry

INTRODUCTION

Laser is one of the newest development that exemplifies medicine and dentistry in the 21st century for patients. The advent of laser use in medicine has been exciting and remarkable since its introduction in the 1960s. Laser may be the standard care in ophthalmology, dermatology and gynecology and several medical specialities use lasers in daily practice.

Patients introduction to laser dentistry initially were limited to the advantages of using laser to treat soft tissue conditions. Some of the patients perceived advantages of laser dentistry including the following:

- Reduced chair side time
- Reduced bleeding, infection and discomfort
- Faster postoperative recovery
- Reduced need for sutures
- Reduced postoperative pain, need for anesthesia, antibiotics and analgesics
- Drill free or scalpel free treatment.

A more recent advantage is the use of lasers in cosmetic dentistry. Laser bleaching, laser bonding and laser tissue recontouring have enhanced and complemented the patient's smile. Many patients believe that using laser, it being a state of art equipment, to perform procedures would give them a more predictable and comfortable result. It gives patients more confidence that the dentist is up-to-date with the latest, and the best technology. Many patients see lasers as a magic wand and perceive it to be a tool leading to advanced medical and dental care.

DENTAL OFFICE IN 21ST CENTURY

There is an immense potential for growth as dentistry enters the 21st century. The first decade itself has ushered many new advances in every aspect of oral health care. Increased awareness among patients has resulted in comprehensive and innovative dental care. The advent of new technology has provided the dentist with better diagnostics and treatment modalities.

A dental appointment is always viewed with apprehension. With the focus shifting towards making this experience as short and stress free as possible, private practitioners and hospital incorporate small but significant details into their practice.

Waiting rooms that are plush and comfortable with multimedia presentations of services provided and their advantages digitalized view of disease progressions and expected progress. Cameras with TV projections to give the patient a clear view of his/her teeth. The technological options are countless and go a long way in alleviating patient's anxiety and reducing chair time. With the advent of laser and this increasing acceptance, chair side time is further reduced and their painless and bloodless procedures further ensure patient comfort during treatment **(Fig. 15.1)**.

Fig. 15.1: Lasers an integral part of a 21st century dental office

The dentist setting up a laser practice must first decide the image he wants to project and the potential clientele. He must then research manufacturers and decide on the instrument that will be of most advantage to achieve his goal. While deciding the instrument he must also compute the average cost per month for investing and in maintaining the instrument. Further, he must calculate how much increase in production the instrument brings. The new technology must be cost effecting and ensure quality treatment.

Investments in high tech equipment must meet the needs of the office, the type of practice image it is hoped to project and the personality of the dentist. The word laser has the ability to attract and draw patients to the office to give the dentist instant credibility that ultimately can add to financial gain. Lasers are one of the first investments for the 21st century dental practice for name recognition and income potential they generate.

Dentist's Team Vision

Dentists across countries attend practice management courses in order to clarify/achieve their goals and visions. There is a universal commitment to provide quality care with personal attention and compassion. Laser practitioners are proud to be a part of a new and technologically advanced era. The latest development in technology helps dentists to provide better services and in doing so, alters patient's perspective towards oral care and makes for a better dental experience.

Laser technology is setting new standards of excellence and represents dentist's continuing commitment to improve the quality of patient's care and comfort.

Each dental practitioner is a valuable asset with invaluable skills. Dentistry is a learning experience and a life long education. Hence, with the introduction of every new technology like laser, a dentist must make time for education and training.

Expectations of the Staff

The most important ingredient of patient care is effective communication.

As is common with most patients who walk into a dental clinic. The level of apprehensions and misinformation is very high. A dentist spends a lot of time with the patient explaining the pros and cons of various treatment options.

A successful laser practice likewise, depends on the information given to the patient regarding the same. The staff should be equipped with ample knowledge of laser. Patient's queries and doubts must be answered to the best of the staff's ability and patient resistance must be attended to one by one. The better informed the patient is about the laser treatment, the lesser time is required for dentist to explain the process, resulting in increased chair side productivity.

ESTABLISHING FEES FOR LASER PROCEDURES

Integration of various technologically advanced equipment into the dental practice has a definite positive financial impact. Dentists performing procedures that they were not possible before justify purchase costs. New procedures like laser bleaching, laser-assisted new attachment procedure (LANAP) can add directly to practice productivity. Biopsies can be performed more easily with a laser rather than with a scalpel.

Assigning fees to procedures that use specialized equipment have three considerations. First for the equipment expenses and the training time to learn new technology. Secondly, fees must be based on goals of production projections. Thirdly, any fee using the specialized equipment must be based on total time of the procedures, including follow-up visits, amount invested and cost of maintenance. The dentist should ideally aim at covering his costs in following years if he invests.

Using all of the aforementioned consideration, the fee should be what the market will bear. If the dentist is known for his/her practice with all of the improved technologies and equipment, fees should be 15 to 20% higher than other dentists in the area. By investing and using this technology, the dentist is providing a superior quality of service.

MARKETING LASER DENTISTRY

Marketing is communicating about the dentist and his or her practice, how the practice can benefit people and why they should seek the dentist's services. It can be described as "the process of providing goods and services for sale."

Marketing or promoting laser technology must start within the office. Internal marketing is marketing or communication done within the office on the current patient population. The patient should be educated on the benefits of laser by the dentist. There are several ways to promote this within the dental practice. The first is a simple flyer or brochure that explains treatments and benefits of the dental laser. This brochure can be placed in all areas of the office, including the waiting room and treatment room, in full view of the patients **(Fig. 15.2)**.

The patients should be given an explanation on why lasers are being introduced to the practice and the dentist's commitment to high quality dental care. The dentist may also want to put together a laser packet, a series of articles and manufacturer's literature that can be sent to existing patients and to prospective patients who contact the office.

In every advertisement, bulletin board, holiday card and every other promotion, the dentist must mention lasers. The phrase 'laser dentistry' should be included on all office printed material (i.e. business cards, website,

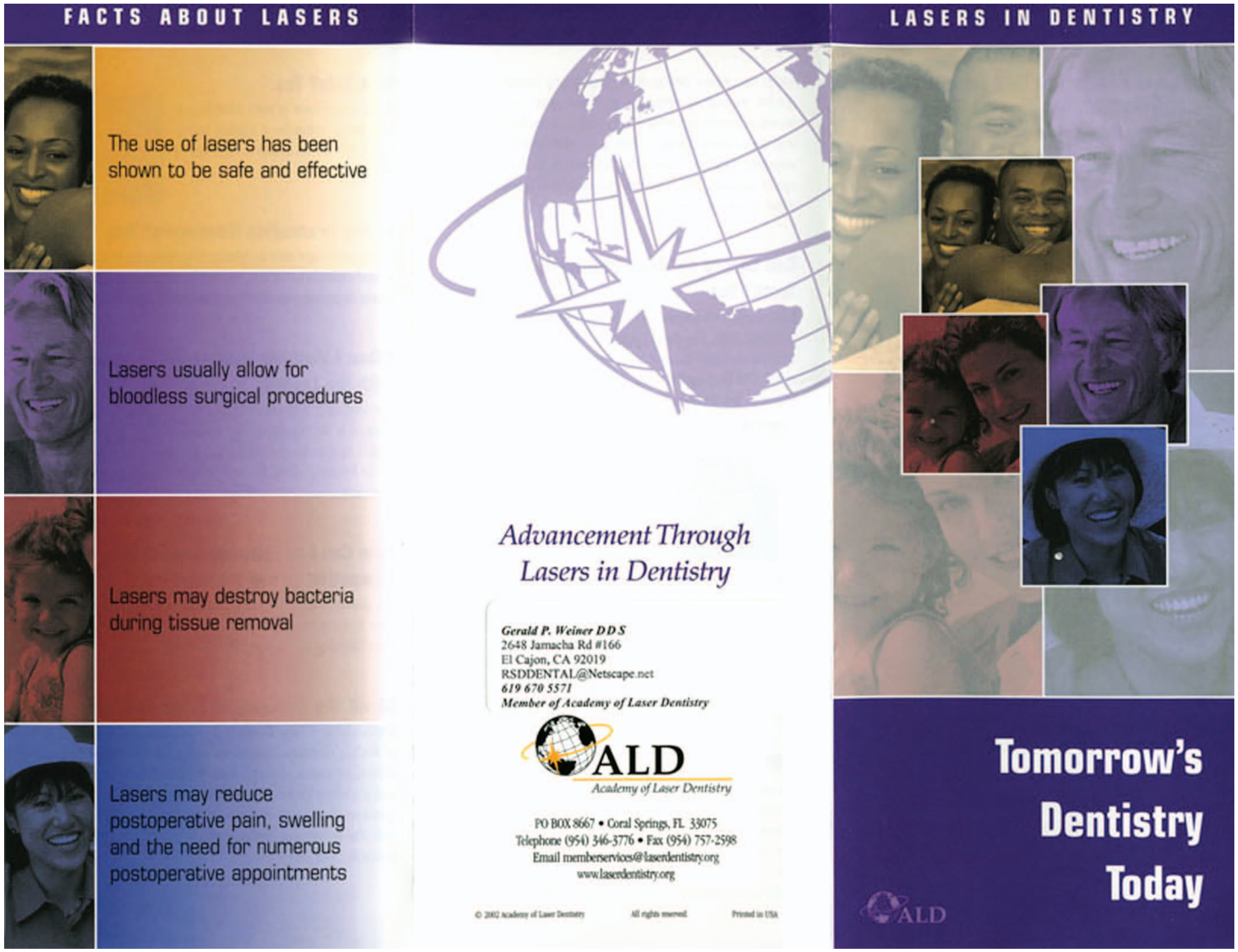


Fig. 15.2: Example of a brochure explaining the benefits of laser assisted dentistry to the patients (*Brochure courtesy:* Academy of Laser Dentistry)

practice brochures, etc.) the dental office generates and information on lasers should be framed on the walls of the practice. Existing patients know and trust the dentist. It makes good sense to start the communication process with them. The dentist may also want to include a telephone on hold service that describes the new laser technology.

After internal marketing plans are implemented, external marketing can be started.

The first type of external marketing the dentist should use is the press release. The dentist's names, address, telephone number, fax number and whom to contact for more information should be put on the press releases. A brief and catchy headline in few words. The press release should be of one or two pages. Photos are always good idea to include with press releases.

Any press release publication and exposure should be followed by printed ads to promote the new laser high tech image. Whether print media, radio, or television spots are chosen, repetition is the key. Promotion must be done for a period of 3 to 6 months to see results.

Direct mail is also a form of external marketing. The dentist should select a targeted market and purchase a mailing list. It should contain all the details about the laser benefits and how using lasers in dental practice makes the procedures easier, more comfortable and faster. The dentist should track the number of responses received and try different headlines with each new mailing. The direct mail pieces should be sent in segments on a weekly basis. Lastly word of mouth is the strongest advertisement. Ensure consistent and stress free procedures that deliver promised results to the patients.

SUMMARY

Laser is rapidly being recognized as the standard of care for many procedures. It is used in many disciplines of dentistry. Integration of lasers into dental practice has provided superior care with less discomfort. Successful integration of lasers into dental practice takes time and effort on part of the dentist. Internal and external marketing plans are essential for the dentist to recoup his investment in this new technology. Restructuring of fee schedules reflect superior laser based care.

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Index