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Working Mechanism of Lasers in Dentistry

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Introduction

Newer advancements are usually seen as a part of everyday technology, and they open new doors for human endeavours. One such advancement is the LASER, which has become a part of modern medical and dental practice. Once considered as a part of complex technology, these lasers have become an adjunct or an alternative to the traditional approaches.

"LASER" is an acronym for "Light Amplification by Stimulated Emission of Radiation". Light is a form of electromagnetic radiation which behaves as a wave and a particle. LASER, a form of light, is an optical source that emits a photon in a coherent beam. LASER light occurs through the amplification of stimulated emission. Since the emission energy is unique relative to its source and of known measurable quantity, the light is of a single wavelength (monochromatic). The high-energy, single-wavelength light is produced in a spatially stable form which will be collimated (non-divergent), with successive waveforms that are in phase or coherent in nature.

Though the laser technology in medicine was first introduced in 1963, it was marketed in dentistry only in the year 1989. As a primary component of the modern communication systems, these lasers are used for both in diagnostic and therapeutic purpose as an adjunct or alternative to traditional approaches.

The target tissue on which the laser acts by a process called absorption usually consists of hard tissue (natural tooth structure, carious enamel, dentin, dental calculus) and soft tissues (gingiva). Low-level lasers occupy a major part in diagnostics, therapeutics and in research. Diagnosis of dental caries, subgingival calculus, pulpal blood flow, periodontal diseases and other soft tissue lesions have been made by lasers. Surgical procedures like operculectomy, excision of the benign lesion in the form of fibromas and epulis, removal of redundant gingival tissue and aberrant frenum are also done by these lasers.

Laser Physics

A Study of each word offers an understanding of the basic principles.

Light

Light is a form of electromagnetic Energy that has dual nature of particle and wave. Photon is the basic unit of Energy. Ordinary light is a diffuse white glow, although it is the sum of many colours of the visible spectrum (VIBGYOR). Laser light has one specific colour, which may be visible or invisible. This property is termed as 'Monochromacity'.[2,11]

Laser light possesses three additional features: collimation, coherency, and efficiency. Collimation refers to the point that the beam is having specific spatial boundaries, that ensures which there is a constant size and shape of the beam emitted from the laser cavity. A dental X-ray machine produces radiation with this property.

Coherency means that the light waves produced in the instrument are all the same. They are all in phase with one another and have identical wave shapes; that is, all the peaks and valleys are equivalent. The clinically useful feature of laser light is efficiency. Using the table lamp as an example, a large amount of heat is produced as a by-product of illumination. A 100-watt light bulb produces about 20 watts of luminescence and approximately 80 watts of invisible radiant Energy that warms the area surrounding it but does not provide light; however, 2 watts of Nd:YAG laser light which provides the thermal Energy to precisely incise a gingival papilla.[12]

There are three measurements that can define the wave of photons produced by the laser. They are 1) velocity, the speed of light; 2) amplitude, the total height of the wave oscillation from top of the peak to the bottom on a vertical axis and 3) wavelength, is the distance between any two corresponding points on the wave on the horizontal or vertical axes. Larger the amplitude, greater the amount of useful work that can be performed. This measurement of physical size suggests how the laser light reacts with the tissues. The laser wavelength is measured in microns (10^{-6}m) or nanometers (10^{-9}m).

Amplification

Amplification is a process that occurs within the laser. Knowledge in the components of a laser instrument is required in understanding how light is produced. An optical cavity is at the centre, and the core of the cavity is composed of molecules, chemical elements, compounds and is known as the active medium. Lasers are usually named on the basis of material in the active medium, which can be containing gas, a crystal, or a solid-state semiconductor. There are mainly two gaseous active medium lasers used in dentistry; Argon and CO_2. The remainder that is available is solid-state semiconductor wafers made with multiple layers of metals such as gallium, aluminium, indium, and arsenic or solid rods of garnet crystal grown with various combinations of yttrium, aluminium, scandium and gallium and then doped with the elements of chromium, neodymium, or erbium. There are two mirrors, one at each end of the optical cavity, placed parallel to each other.

Surrounding this core is an excitation source, either a flash lamp strobe device or an electrical coil, which provides the Energy into the active medium. A cooling system, focusing lenses, and other controls complete the mechanical components.[6] The excitation source provides Energy so that stimulated emission will occur within the active medium. The photons are then amplified by the mirrors and emerge as laser light.[3]

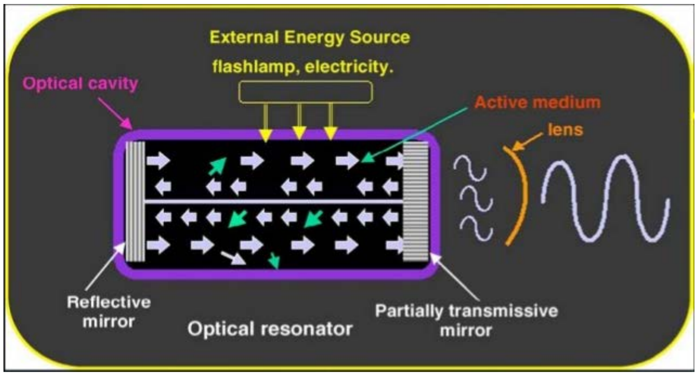
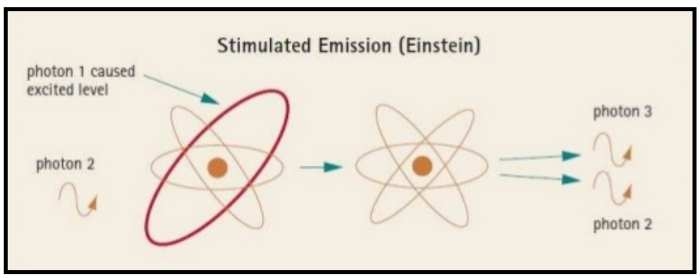


Figure 1: Basic components of a laser

Stimulated Emission

Max Planck (1900) introduced the term 'stimulated emission' which is based on the quantum theory of physics. A 'quantum', the smallest unit of Energy, is absorbed by the electron of an atom or molecule, causing a brief excitation. Then a quantum is released by a process termed 'spontaneous emission'.[6,13,14]

Figure 2: Stimulated emission: Photon 2 is an additional



quantum of Energy that enters the field of the already excited atom. There is an emission of photon 3, and the atom returns to its resting state.

Albert Einstein theorized that if an additional quantum of Energy travelling in the field of the excited atom has the same excitation energy level would result in the release of two quanta by a phenomenon termed 'stimulated emission'. This process would occur just before the atom could undergo spontaneous emission. These photons are able to energize more atoms which further emit additional photons, stimulating more surrounding atoms. If the conditions are right, a population inversion occurs, which means that a vast majority of the atoms of the active medium are in the excited rather than the resting state. There must be a constant source of Energy called a pumping mechanism, to maintain this excitation.

The mirrors which are at each end of the active medium reflect these photons back and forth to allow further stimulated emission and passes through the active medium increasing the power of the photon beam: Known as of amplification. There is some heat liberated in the process, and the optical cavity must be cooled. The parallelism of the mirrors ensures that the light is collimated. One of the mirrors is selectively transmissive, allowing the light of sufficient Energy to exit the optical cavity. [15]

Radiation

Radiation refers to light waves produced by the laser as a specific form of electromagnetic Energy. The electromagnetic spectrum is an entire collection of wavelengths ranging from gamma rays (10^{-12}m) to radio waves (300nm). The very short wavelengths those below approximately 300 nm are termed ionizing. This term refers to the fact that higher-frequency (smaller wavelength) radiation has a large photon momentum measured in electron volts per photon. This higher photon energy can deeply penetrate biologic tissue and produce charged atoms and molecules.

Wavelengths larger than 300nm have less photon energy and cause excitation and heating of the tissue with which they interact. All available dental lasers have emission wavelengths approximately 500nm to 10,600nm. Lasers are within the visible/invisible infrared portion of the electromagnetic spectrum and emit thermal radiation. The dividing line between the ionizing (i.e., the cellular DNA mutagenic portion of the spectrum) and the non-ionizing portion is on the junction of ultraviolet and visible violet light.[6,16]

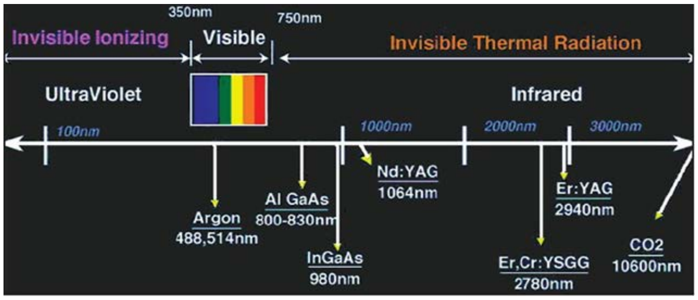


Figure 3: Electromagnetic Spectrum and Dental Laser Wavelengths

Components of Laser

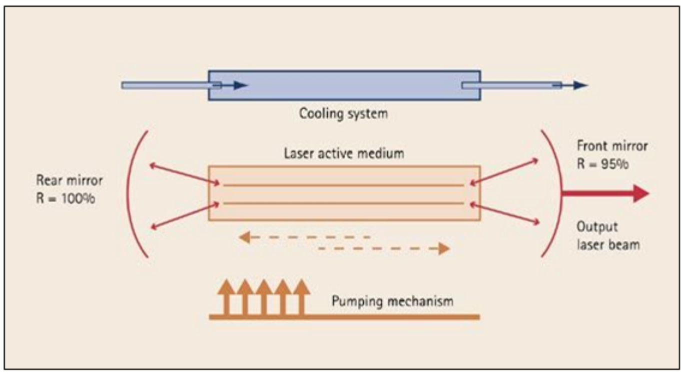


Figure 4: Components of Laser

a. Active Medium

The active medium which is positioned within the laser cavity has an internally-polished tube with mirrors that are co-axially positioned at each end and surrounded by the external energizing input or pumping Mechanism. The 'active medium', e.g.CO^2, Nd: YAG, defines the type of laser and the emission wavelength of it i.e. (10,600 nm and 1,064 nm respectively). Atoms of this active medium are absorbed by the process of light emission. The first used 'dental' laser used a crystal of neodymium-doped yttrium aluminium garnet (Nd: YAG) as its active medium.[3]

b. Pumping Mechanism

Pumping Mechanism represents a man-made source of primary Energy that ignites the active medium. Mostly its a light source, either an arclight or flashlight, which can be a diode laser Unit or an electromagnetic coil. Energy from a primary source is absorbed by the active medium inside resulting in the production of laser light, But this process is ineffective, with only some 3-10% of incident energy converting in laser light, the rest being transferred to heat energy[3]

c. Optical Resonator

Laser light produced by the stimulated active medium bounces back and forth through the axis of the laser cavity using two mirrors placed at either end and thus amplifying the power. The distal mirror is totally reflective, and the proximal mirror is partly transmissive so that at a given energy density, a laser light will escape being transmitted to the target tissue[3]

d. Cooling System

Laser light propagation results in heat production,By increasing the power output of the laser, with heavy-duty tissue cutting lasers, the cooling system represents the mightiest component. Co-axial coolant systems may be air or water-assisted.[3]

e. Control Panel

This allows variation in power output with time, above all that is defined by the pumping mechanism frequency. Other facilities may allow wavelength change (multi-laser instruments) and print-out of delivered laser energy during clinical use.[3]

Classification Of Lasers

Hamid Reza Khalinghi in 2010, reviewed the classification based on the power as mentioned by Mokameli and Eslami.[8]

1. High Power Lasers (Hard, Hot)

These lasers increase tissue kinetic Energy and produce heat. And thus as a result, they leave their therapeutic effects through thermal interactions on tissues. These effects include necrosis, carbonization, vaporization, coagulation and denaturation. These lasers usually have an output power of more than 500 m W.

2. Intermediate-power lasers

These lasers leave their therapeutic effect without producing significant heat. To shorten treatment period length and to accelerate the therapeutic effect in some cases, low-power lasers are replaced by intermediate with output powers ranging from 250-500 m W.

3. Low-power lasers (soft, cold)

These lasers have no thermal effect on tissues and produce a reaction in cells through light, called photobiostimulation or photo biochemical reaction. The output power of these lasers is far less than 250 mW.

Table 1: Dr David M. Roshkind, 2011 has classified the soft tissue lasers as follows [9].

Soft Tissue Lasers	Wave length		Active Medium
Visible	KTP	532nm	Solid Crystal
Near Infrared	AIGaAs GaAs InGaAs InGaAsP Nd: YAG	810nm 940nm 980nm 1064nm 1064nm	Solid State diode Solid State diode Solid State diode Solid State diode Solid crystal
Mid infrared	Er, Cr:YSGG Er:YAG	2780nm 2940nm	Solid crystal Solid crystal
Far infrared	CO_2	1,600nm	Gas

Laser Energy and Tissue Temperature

The principal effect of laser energy is photothermal (i.e., the conversion of light Energy into heat). This thermal effect of laser energy on tissue depends on the degree of temperature rise and the corresponding reaction of the interstitial and intracellular Water. The rate of temperature rise plays in an important role in the overall effect and is dependent on several factors, such as cooling of the surgical site and the surrounding tissue's ability to dissipate the heat to the surroundings. The various laser parameters used for the procedure are also important, such as the emission mode, the power density, and the time of exposure. As the laser energy is absorbed, heating occurs (Table-2).

The first event is **hyperthermia**, which occurs when the tissue is elevated above normal temperature but is not destroyed. At temperatures of approximately 600C, proteins begin to denature (**protein denaturation**) without any vaporization of the underlying tissue. The tissue whitens or blanches, which can be seen when an egg white's albumin changes from clear to milky during cooking. This phenomenon is useful in surgically removing diseased granulomatous tissue because if the tissue temperature can be controlled, the biologically healthy portion can remain intact. **Coagulation** refers to the irreversible damage to tissue, converting liquid into a soft semi-solid mass. This process produces the desired effect of hemostasis, by the contraction of the wall of the vessel [wall24]

Soft tissue edges can be "**welded**" together with uniform heating to 70°C to 80°C where there is the adherence of the layers because of stickiness due to the collagen molecule's helical unfolding and intertwining with adjacent segments. When the target tissue which contains Water is elevated to a temperature of 100°C, **vaporization** of the Water within the tissue is also called as **ablation**. There is a physical change of state, i.e. the solid and liquid components turn into vapour in the form of smoke or steam. Because any soft tissue is composed of a high percentage of Water, excision of soft tissue commences at this temperature. The apatite crystals and other minerals present in dental hard tissue are not ablated at this temperature, but the water component is vaporized, and the resulting jet of steam expands and then explodes the surrounding matter into small particles. This mixture of steam and solids is then later on suctioned away. This process of micro-explosion of the apatite crystal is termed as "**spallation**".[20]

If the tissue temperature continues to be raised to about 200°C, it is dehydrated and then burned in the presence of air. Carbon, as the end product (**carbonization**), absorbs all wavelengths. Thus, if laser energy continues to be applied, the surface carbonized layer absorbs the incident beam, becoming a heat sink and preventing normal tissue ablation. The heat conduction causes collateral thermal trauma to a wide area.

Table 2: Target tissue effects in relation to temperature

Tissue Temperature in °celsius	**Observed effect**
37-50	Hyperthermia
60-70	Protein denaturation, Coagulation
70-80	Welding
100-150	Vaporization, ablation
>200	Carbonization

Laser – Tissue Interaction

Laser light can have four different interactions with the target tissue, depending on the optical properties of that tissue. Dental structures have a complex composition, and these four phenomena occur together in some degree relative to each other—the first and most desired interaction in the absorption of the laser energy by the intended tissue. The amount of Energy that absorbed by the tissue depends on the tissue characteristics, such as pigmentation and water content, and on the laser wavelength and emission mode. Tissue compounds called chromophores preferentially absorb certain wavelengths.

Haemoglobin is the molecule that transports oxygen to tissue, reflects red wavelengths, imparting colour to arterial blood. It therefore strongly absorbs blue and green wavelengths. Venous blood, containing less oxygen, absorbs more red light and appears darker. The pigment melanin, which imparts colour to skin, is strongly absorbed short-wavelength lasers such as Diode and Nd:YAG.

Water, the universally present molecule, has varying degrees of absorption by different wavelengths. Dental structures have a different amount of water content by weight. A ranking from lowest to highest would show enamel (with 2% to 3%), dentin, bone, calculus, caries, and soft tissue (at about 70%). Hydroxyapatite is the principal crystalline component of dental hard tissues that has a wide range of absorption depending on the wavelength.[25]

Effects of Laser Irradiation On Tissue

When laser light impinges on tissue, it can reflect, scatter, be absorbed or transmitted to the surrounding tissue.

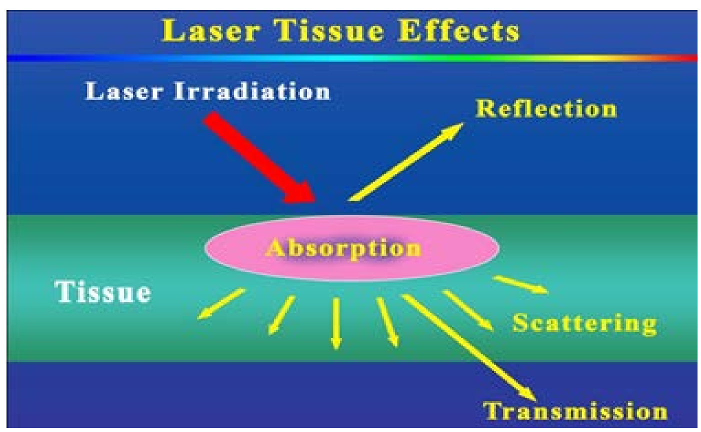
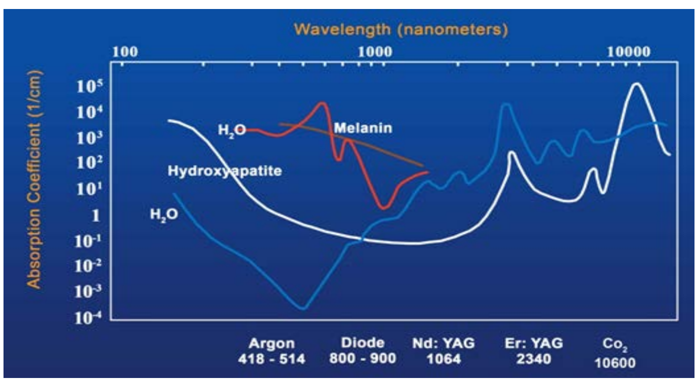


Figure 5: Laser-Tissue Effects

Absorption of the laser light by the tissue is the primary and beneficial effect of laser energy. The goal of dental laser surgery is to optimize these photobiologic effects. Using the thermal photo conversion of Energy, incisions and excisions with accompanying precision and hemostasis are some of the many advantages of laser devices. There are photochemical effects from laser light that can stimulate chemical reactions (e.g., the curing of composite resin) and thus breaking of chemical bonds (e.g., using photosensitized drugs exposed to laser light to destroy tumour cells, which is known as a process called photodynamic therapy).

In general, the shorter wavelengths (from about 500-100 nm) are readily absorbed in pigmented tissues and blood elements. Argon is highly attenuated by haemoglobin. Diode and Nd:YAG has a high affinity for melanin and less interaction with haemoglobin and other blood pigments. The longer wavelengths are more interactive with Water and hydroxyapatite crystals. The largest absorption spectrum peak for Water is just below 3000 nm, which is at the Er:YAG wavelength. Erbium is also well absorbed by hydroxyapatite. CO_2 at 10,600 nm wavelength is well absorbed by Water and has the greatest affinity for tooth structure.[26]



Graph-1: Approximate absorption curves of different dental compounds by various wavelengths of dental **lasers.**

The second effect is **the transmission** of the laser energy directly through the tissue with no effect on the target tissue, the inverse of absorption. This effect is highly dependent on the wavelength of laser light. , For example, Water is relatively transparent to the shorter wavelengths like argon, diode, and Nd:YAG, whereas tissue fluids readily absorb the erbium family and CO_2 at the outer surface, so there is little Energy transmitted to adjacent tissues. The depth of the focused laser beam varies with the speed of movement and the power density. In general, the erbium family acts mainly on the surface, with an absorption depth of approximately 0.01 mm, whereas the 800-nm diodes are transmitted through the tissue to depths up to 100 nm, a factor of 10,000. As another example, the diode and Nd:YAG lasers are transmitted through the lens, iris, and cornea of the eye and are absorbed on the retina.[20]

The third effect is **the reflection**, which is the beam redirecting itself off of the surface, having no effect on the target tissue. A caries-detecting laser light device uses the reflected light to measure the degree of sound tooth structure. The reflected light could maintain its collimation in a narrow beam or become more diffuse.

The laser beam generally becomes more divergent as the distance from the handpiece increases. However, the beam from some lasers can have adequate Energy at distances over 3 m. This reflection can be dangerous because it can be directed to an unintentional target, such as the eyes; which is a major safety concern for laser operation. The safety aspects of laser use are discussed later.

The fourth effect is a **scattering** phenomenon of the laser light, weakening the intended Energy and possibly producing no useful biologic effect. Scattering of the laser beam could cause heat transfer to the tissue adjacent to the surgical site, and unwanted damage could occur at the site. However, a beam which is deflected in different directions is useful in facilitating the curing of composite resin or in covering a broad area [of the tissue 20]

A special group of lasers that emit in the ultraviolet ionizing range, the excimers, have enough photon energy to directly break the chemical bond of an organic molecule without any thermal damage. These are being investigated for hard tissue ablation procedures. Certain biological pigments, when absorbing laser light, can fluoresce, which can

be used for caries detection within teeth. A laser can be used with powers well below the surgical threshold for biostimulation, producing more rapid wound healing, pain relief, increased collagen growth, and a general anti-inflammatory effect. The pulse of laser energy into a crystalline structure can produce an audible shock wave, which could explode or pulverize the tissue with that mechanical Energy. This is an example of the photoacoustic effect of laser light.[27]

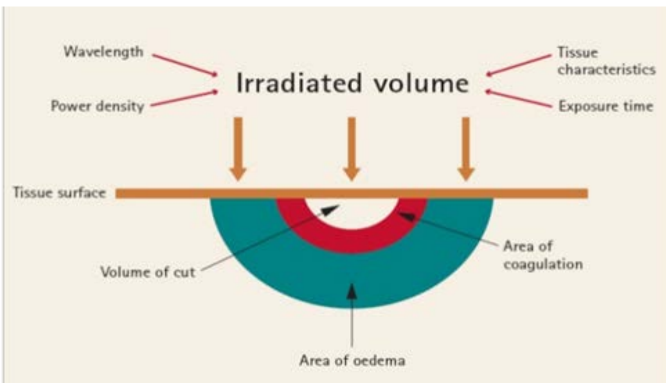


Figure 6: Theoretical Zones of Tissue Change Associated With Soft Tissue Exposure

To Laser Light

Laser Wavelengths Used In Dentistry

There are several laser manufacturers with various product offerings, details about companies and their instruments. The marketplace continues to change, and so does the availability of the devices. The following are brief descriptions of laser devices that have dental applications. The lasers are named based on their active medium, wavelength, delivery system, emission mode(s), tissue absorption, and clinical applications. The shortest wavelength is listed first.

Table 3: Current laser manufacturers and their wavelengths

Manufacturer	**Wavelength in Nanometers (nm)**	**Absorbed by**
American Dental Technologies	Nd:YAG 1064	Pigment
American Dental Technologies	Diode 810-830	Pigment
Biolitec	Diode 980	Pigment
Biolase	Er,Cr:YSGG 2790	Water
Biolase	Diode 810-830	Pigment
Hoya Conbio	Er: YAG 2940	Water
Lares Research	Nd:YAG 1064	Pigment
Millenium Dental Technologies	Nd:YAG 1064	Pigment
OpusDent	CO_2 10,600	Water
OpusDent	Diode 810-830	Pigment
OpusDent	Er:YAG 810-830	Water
Zap Lasers	Diode 810-830	Pigment

Table 4: Types of Lasers and their Wavelength in dentistry

Laser Type	Wavelength (nm)	Mode of Operation	Power	Applications
Argon	488,514	CW	1-20	• Curing Composite resin • Excision and Photocoagulation of the vascular lesion-caries detection
Diode	650,980	CW	1-10	• Biostimulation Pulsed

		Pulsed		• Excision of soft tissue pathology. • Gingivectomy
Nd:YAG	1064	CW Pulsed	50-100	• Coagulation pulsed • Cutting (frenectomy, gingivectomy) • Subgingival curettage
Ho:YAG	2100	Pulsed	25	• Arthroscopic surgery for TMJ • Gingivectomy, frenectomy, implant exposure.

Er:YAG	2940	Pulsed	3	• Cavity preparation, periodontal treatment, excision and incision of soft tissue (for dental use)
CO_2	9600, 10600	CW	10-100	• For excision of benign and malignant lesion, cutting, drilling, vaporization of tissue and caries prevention.

Delivery Systems

The field of lasers in general practice essentially began with the introduction of the American Dental Laser (Birmingham, Michigan) dLase 300 neodymium: yttrium-aluminium-garnet (Nd:YAG) laser in 1990. Before the introduction of this instrument, most dental lasers used bulky articulated arms for their delivery systems. These articulated arms were not conducive to the practice of general dentistry, owing to the long learning curve needed to master their use and the difficulty of delivering the laser energy to the entire oral cavity. Articulated arm delivery systems consist of a series of rigid hollow tubes with mirrors at each joint (called a knuckle) that reflect the Energy down the length of the tube. These joints exit to allow the delivery arm to be bent and configured in such a way as to bring the handpiece close to the target tissue.

The laser energy exits the tube through a handpiece (Figure-7). Strauss described the intraoral use of an articulated arm delivery system. He stated that it is a difficult way to remove discrete lesions within the oral cavity because of the awkward three-dimensional manoeuvrability of the arm. A second problem with the use of articulated arms is the alignment of the mirrors. To transmit the laser energy efficiently, the mirrors at each knuckle must be aligned precisely. A misalignment of the mirrors could cause a drop-off in the amount of Energy transmitted to the handpiece.

The mirrors could go out of alignment through the normal use of moving the articulated arm for each new procedure or if the laser is moved from treatment room to treatment room. Articulated arm delivery systems are noncontact systems (i.e., handpiece or its attachments do not come into contact with the target tissue). Dentists are familiar with contact technology: the fissure bur contacts the enamel during tooth preparation. The curet contacts the root surface during scaling and root planing. The scalpel contacts the soft tissue when incising. Using a technology in which there is no contact between the instrument and target tissue can be challenging at first. This is one major reason for a longer learning curve with these instruments compared with contact technology instruments.

Figure 7: Articulated arm delivery system

The American Dental Laser dLase Nd:YAG system was the first such instrument to use a fiberoptic delivery system. This fiberoptic technology allows for contact with the target tissue. The fiberoptic cables are attached to a small handpiece similar in size to a dental turbine and are available in sizes ranging from 200µm in diameter to 1000µm in diameter. Fiberoptic cables also are relatively flexible. This flexibility allows for easy transmission of the laser energy throughout the oral cavity, including into periodontal pockets. Fiberoptic delivery and articulated arm systems are not the only two delivery systems currently on the market. One manufacturer has developed a hollow waveguide delivery system. In contrast to an articulated arm system, this waveguide is a single long, semiflexible tube, without knuckles or mirrors. The laser energy is transmitted along the reflective inner lumen of this tube and exits through a handpiece at the end of the tube (Figure-8). This handpiece comes with various attachments that the dentist may select, depending on the procedure to be performed, and may be used either in contact or out of contact with the target tissue. The final delivery system is the air-cooled fiberoptic delivery system. This type of delivery system is unique to the erbium family of lasers. A conventional fiberoptic delivery system cannot transmit the wavelength of the erbium family of lasers, owing to the specific characteristics of the erbium wavelength.

These special air-cooled fibres terminate in a handpiece with quartz or sapphire tips. These tips are used slightly (1-2 mm) out of contact with the target tissue. Since the introduction of the dLase 300, general practitioners have seen the number of wavelengths and manufacturers available to them increase from one manufacturer of one wavelength to eight different manufacturers offering six different wavelengths.[28]

Figure 8: Waveguide Delivery System

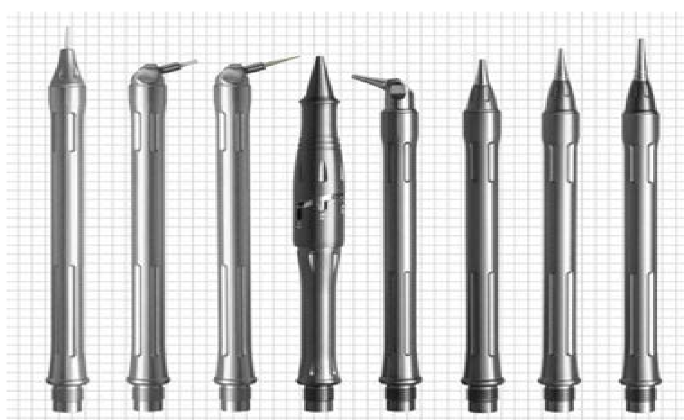


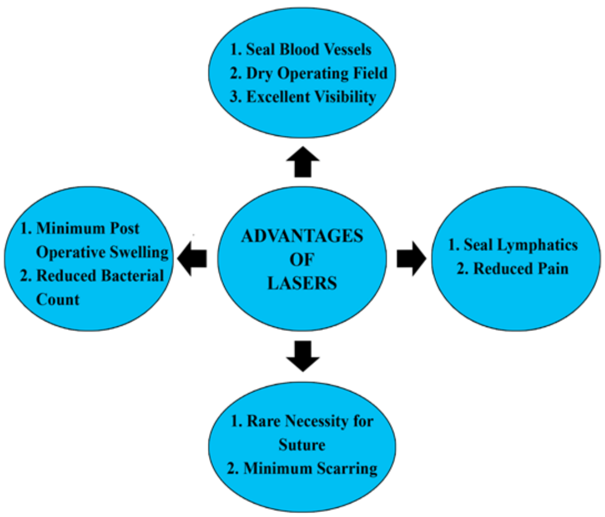
Figure 9: Fiber optic cables of various diameters and hand pieces from a waveguide delivery system

Biologic Rationale for The Use Of Lasers In Medicine And Dentistry

A Physician or dentist should consider the following factors:

1. Interaction between the target tissue, wavelength and surrounding tissue.
2. Soft tissue lasers produce excellent results.
3. Selection of correct operating procedure (joules, hertz, pulse duration).

Advantages of Lasers

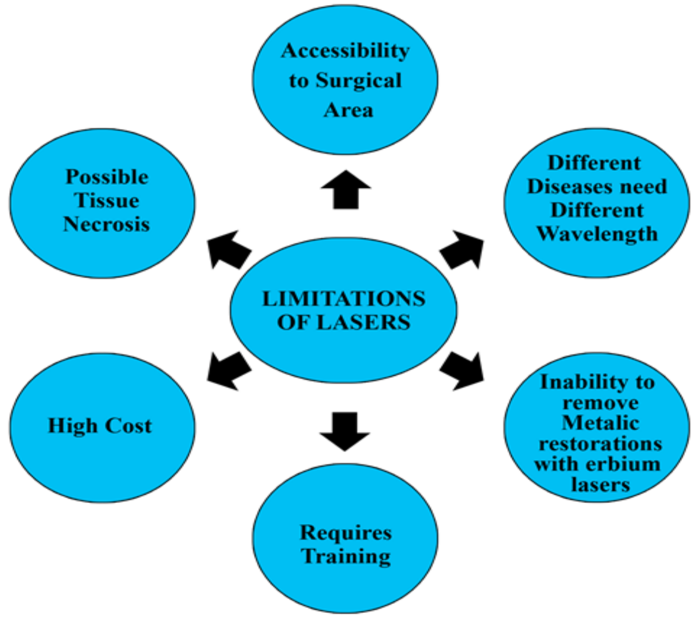


Flow Chart 1: Advantages of Lasers

Blum JF et al (1997) found that the antibacterial effect of the lasers are frequency dependent as he found that only a frequency of 30 Hz inhibited the growth of Streptococcus mitis using a Nd:YAP laser.

Kranendonk A et al (2010) did an in vitro study, in which Nd:YAG laser used was found to be effective for total killing of the six tested periodontal pathogen

Limitations of Lasers



Flow Chart 2: Limitations of Lasers

References

1. Walsh LJ. The current status of laser application in dentistry. Australian Dental journal 2003;48;(3);146-155.
2. Scbwarz F, Aoki A, Sculean A et al. The impact of laser application on periodontal and peri-implant wound healing. Periodontology 2000, Vol. 51, 2009, 79-108.
3. Slot DE, Kranendonk AA, Paraskevas S et al. The Effect of a Pulsed Nd:YAG Laser in Non-Surgical Periodontal Therapy. J Periodontol 2009;80;1041-1056.
4. Terry D. Myers, John G. Sulewski, Evaluating dental lasers; what the clinician should know, Dent Clin N Am 48 (2004) 1127-1144.
5. Parker S. Introduction, history of lasers and laser light production. British Dental Journal 2007;202;21-31.
6. S. Parker. Low-Level Laser Use In Dentistry. British Dental Journal Volume 202 No. 3 Feb 10 2007.

7. Maiman T. Stimulated optical radiation in ruby. Nature 1960;187:493-4.
8. Epstein JB, Oakley C, Millner A, Emerton S, van den Meij E, Le N. The utility of toluidine blue application as a diagnostic aid in patients previously treated for upper oropharyngeal carcinoma. Oral surg Oral Med Oral Pathol Oral Radiol Endod 1997; 83:537-547.
9. Dougherty TJ. An update on photodynamic therapy applications. J Clin Laser Med Surg 2002;20:3-7.
10. Fleming MG, Maillet WA. Photopolymerization of composite resin using the argon laser. J Can Dent Assoc 1999;65:447-450.
11. Davies AK, Cundall RB, Dandiker Y, Sifkin MA. Photooxidation of tetracycline adsorbed onto hydroxyapatite in relation to the light-indueed staining of teeth. J Dent Res 1985;64:936-939.
12. The photonics dictionary 43rd edition. Pittsfield (MA); Laurin Publishing; 1997.
13. Myers TD. Lasers in dentistry: their application in clinical practice. J Am Dent Assoc 1991; 122:46-50.
14. Bohr N. The Theory of spectra and atomic constitution. 2nd edition. Cambridge: Cambridge University Press; 1922.
15. Dictionary of scientific biography. New York; Charles Scribner's Son; 1971.
16. Einstein A. Zur Quantum Theorie Der Stralung. Verk Deutsch Phys Ges 1916; 18:318.
17. The Columbia electronic encyclopedia. New York: Columbia University Press: 2003.
18. Prakash O. Ram R S. Simple designs to measure efficiency of different types of monochromators. J Opt 1996; 27:241-245.
19. Inberg A, Oksman M, Ben-David M, Croitoru N. Hollow waveguide for mid and thermal infrared radiation. J Clin Laser Med Surg 1998; 16:127-133.
20. Merberg G N, Current status of infrared li ber optics for medical laser power delivery Lasers Surg Med 1993; 13:572-576.
21. Donald J. Coluzzi, Fundamentals of dental lasers: sciences and instruments, Dent Clin N Am 48 O 751-770.
22. Inberg A, Oksman M, Ben-David M, Croitoru N. Hollow waveguide for mid and thermal infrared radiation. J Clin Laser Med Surg 1998; 16: 127-133.
23. Konorov S O. Mitrokhin V P, Fedotov A B et al. Hollow core photonic-crystal fibers for laser dentistry. Phys Med Biol 2004; 49: 1359-1368.
24. Apel C, Franzen R, Meister J, Sarrafzadegan H, Thelen S, Gutknecht N, Influence of the pulse duration of an Er: Yag laser system on the ablation threshold of dental enamel, Laser Med Sci 2002; 17: 253-257.
25. Lasers in Dentistry: Revolution of Dental Treatment in The New Millennium. Proceedings of the 8th International Congress on Lasers in Dentistry, held in Yokohama, Japan, between 31 July and 2 August 200. International Congress Series Volume 1248, May 2003, Pages 13-19.
26. Frank F. Laser light and tissue biophysical aspects of medical laser application. SPID Lasers Med 1989; 1353:37-45.
27. Dederich, D.N,: Laser/tissue interaction: What happens to laser light when it strikes tissue? JADA, 1993; 124(2): 57-61.
28. Robert A. Convissar, The biologic rationale for the use of lasers in dentistry, Dent Clin N Am 48(20045) 771-794.