Lasers In Periodontics

Dr Padma. R Professor and H.O.D
Dr Neha Bhutani Postgraduate student,
Dept of Periodontics ,St. Joseph dental college, Eluru .

With in dentistry in the high tech era of the 1990's there are many technologic innovations to enhance treatment; however no instrument is more representative of the term high tech than lasers. Dental procedures performed today with lasers, are so effective that they set a new standard of care. When lasers are properly used within ethical envelope of clinical dentistry, they offer dentist a superb treatment modality for various common clinical conditions.[1]

'LASER' is an acronym for Light Amplification by Stimulated Emission of Radiation. The physical principle of laser was developed from Einstein's Theories in the early 1900s and the first device was introduced in 1960 by Maiman. . Laser light is a man-made single photon wavelength. The process of lasing occurs when an excited atom is stimulated to emit a photon.[2]

History of Lasers in Periodontics

Based on Albert Einstein's theory of spontaneous and stimulated emission of radiation, Maiman developed the first laser prototype in 1960. Shortly thereafter, In 1961 Snitzer published the prototype for the Nd:YAG laser. The first application of a laser to dental tissue was reported by Goldman et al.

History of laser therapy as applied to periodontics began in the early 1960's with the development of argon, carbon dioxide lasers and neodymium: yttrium aluminium garnet (Nd:YAG) lasers. The next major advance in the development of laser technology for soft tissue use was the introduction of a contact delivery system for the Nd: YAG laser in 1984. [3]

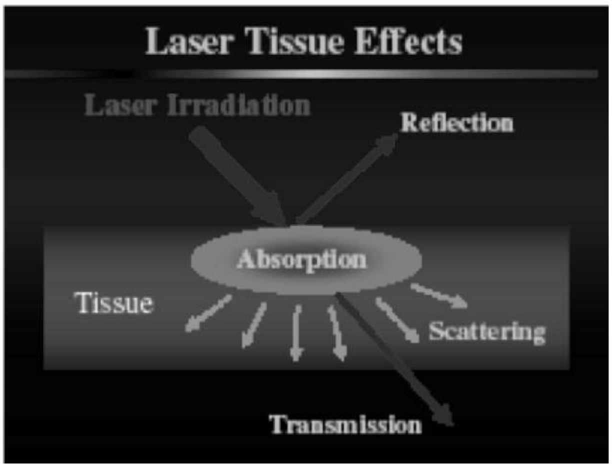
Effects of lasers on tissue

The light energy from a laser can have four different interactions with the target tissue, and these interactions will depend on the optical properties of that tissue. (Fig.1)

The first is reflection, which is simply the beam redirecting itself off of the surface, having no effect on the target tissue. The second effect is transmission of the laser energy directly through the tissue, with no effect on the target tissue. The third effect is a scattering of the laser light, weakening the intended energy and possibly producing no useful biological effect.

Absorption of the laser energy by the intended target tissue is the usual desirable effect, and the amount of energy that is absorbed by the tissue depends on the tissue characteristics, such as pigmentation and water content, and on the laser wavelength and emission mode.[4]

Fig .1 Effects of laser on tissues



Types of lasers used in periodontics

Argon lasers

Argon laser emit in the blue green spectrum at 488nm or 510 nm. (Fig.2). The active medium is a gas, and the beam is delivered through an optical fibre. The beam emitted has an affinity for darker coloured tissues, especially haemoglobin, making them excellent coagulators. Argon lasers work in both contact and non contact mode. The green wavelength of 510nm of argon lasers is used primarily for excision, vaporization, and coagulation of soft tissues.

Carbon dioxide lasers

The carbon dioxide laser was first developed by Patel et al in 1964 is a gas laser that emits a wavelength of 10.6 nm in the mid infrared range of electromagnetic spectrum. The carbondioxide lasers are absorbed by wet tissues regardless of tissue colour.

A fiberoptic delivery system is not available for CO_2 lasers. Current delivery systems use either an articulated arm or a hollow waveguide. The hollow waveguide system is more flexible and which is more easily manipulated for intraoral surgery. All CO_2 lasers works through a noncontact mode.

Nd:YAG Lasers

Nd:YAG lasers developed in 1964 by Geusic et al stands for neodymium: Yttrium-aluminium garnet. This solid state laser consists of a crystal of Yttrium-aluminium-garnet doped with neodymium. Emission is in the near infrared range at 1.06nano meters. A major advantage of this laser is that the emission may be delivered by an optical fiber. These lasers are preferentially absorbed by pigmented tissues and have various degrees of optical scattering and penetration in the tissues, minimal absorption and no reflection.

Nd: YAG lasers work by either a contact or noncontact mode. Delivery options include raw fiber delivery in the contact mode or non contact mode, and bare fibres

With pulsed Nd: YAG lasers, peak powers are much higher when compared with CW (continuous wave) output lasers. There are high spikes, with peak powers being 1000 times higher than the average power that is set on the unit. This is followed by a long interpulse interval.

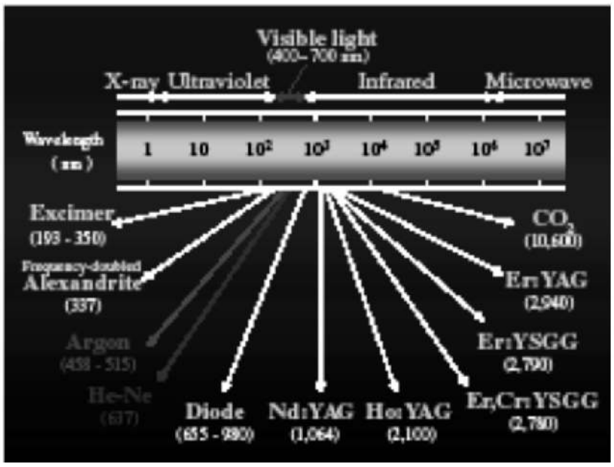
Fibre sizes in Nd:YAG lasers vary from 200 to 800 nano microns. . At lower powers Nd:YAG lasers have dragability when cutting tissues . Because the Nd: YAG wavelength contacts to the pigmented tissues or darker colours, some operators use a black enhancer to speed the actions of the lasers.

Most pulsed Nd:YAG lasers require fiber preparation prior to lasing. The coating around the fiber must be removed and the fiber cleaved to create a working tip. Recently disposable Nd:YAG laser tips have been introduced. The tips come in various sizes, shapes and diameters.

Most dental Nd:YAG lasers works through a pulsed mode. At higher powers and pulses, a super heated gas called plasma can be formed on the tissue surfaces. This surface plasma can further absorb the laser beam as it strikes the tissue surfaces, allowing a decreased amount of energy to reach the actual tissue surface..

It is this plasma that can be responsible for the effects of coagulation, vaporization or cutting. A pressure front can be generated when the plasma is generated slightly below the tissue surface. This pressure front or shock wave can blow out a chip of the corresponding material mechanically.[5]

Fig.2. Wavelength range for different types of lasers



Ho:YAG Laser

The most recent laser approved by the food and drug administration for oral soft tissue use is the Ho:YAG lasers. It is delivered through a fiberoptic carrier, has a wavelength of 2100nm, and the active medium is a crystal. The holmium laser is thallium and holium doped, chromium sensitized YAG crystal. The Ho:YAG laser uses red helium neon laser as an aiming light. It has dragability like argon and Nd:YAG, but it has the least of the three. Ho:YAG, like carbondioxide has affinity for water; this property allows Ho:YAG to be absorbed by aqueous tissue, which then converts its energy to heat with subsequent ablation of tissue.

Like Nd:YAG, Ho:YAG lasers can be used in both the contact and noncontact mode and they are pulsed lasers.[6]

Er:YAG laser

The Er:YAG laser was introduced in 1974 by Zharikov et al as a solid-state laser that generates a light with a wavelength of 2,940 nm.

Of all lasers emitting in the near- and mid-infrared spectral range, the absorption of the Er: YAG laser in water is the greatest because its 2,940nm wavelength coincides with the large absorption band for water.

The absorption coefficient of water of the Er:YAG laser is theoretically 10,000 and 15,000-20,000 times higher than that of the CO2 and the Nd:YAG lasers respectively. Since the Er:YAG laser is well absorbed by all biological tissues that contain water molecules, this laser is indicated not only for the treatment of soft tissues but also for ablation of hard tissues.

The high absorption of the Er:YAG laser into water minimizes thermal influences on the surrounding tissues during irradiation.

In the case of hard tissue procedures, some degree of heat generation is inevitable with the Er:YAG laser, since the Er:YAG laser emits in the infrared region and hard tissues have very low water content.

The recently introduced Erbium, Chromium-doped: Yttrium Scandium-Gallium-Garnet (Er,Cr:YSGG) laser with 2,780 nm wavelength and the Erbium-doped: Yttrium-Scandium-Gallium-Garnet (Er:YSGG) laser with 2,790 nm wavelength, which are more highly absorbed by OH ions than water molecules, are expected to have a performance similar to that of the Er:YAG laser.[7]

Diode laser

The diode laser is a solid-state semiconductor laser that uses a combination of Gallium (Ga), Arsenide (Ar), and other elements such as Aluminum (Al) and Indium (In) to change electrical energy into light energy. The wavelength range is about 800-980 nm. The laser is emitted in continuous-wave and gated-pulsed modes, and is usually operated in a contact method using a flexible fiber optic delivery system.

Laser light at 800-980 nm is poorly absorbed in water, but highly absorbed in haemoglobin and other pigments. The laser is an excellent soft tissue surgical laser, indicated for cutting and coagulating gingiva and oral mucosa, and for soft tissue curettage or sulcular debridement. [8]

Laser Types	Common abbrev-ation	Wave-length	Waveform	Delivery tip	Periodontal Application
Carbon Dioxide ablation,	Co_2	10.6µm	Gated or continuous	Hollow waveguide	Incision, curettage
Neodymiumyttrium ablation, Alluminium-garnet	Nd:YAG	1.064µm	Pulsed	Flexible fibreoptic system and contact required	Incision, curettage and bacterial elimination
Holmium-yttrium ablation, aluminium garnet	Ho:YAG	2.1µm	Pulsed	Flexible fibre optic system contact required	Incision, subgingival curratage and bacterial elimination
Erbiumchromium ablation, yttrium selenium galliumgarnet	ErCr-YSGG	2.94µm	Pulsed	Sapphire crystal inserts surface contact required	Incision, subgingival curettage and bacterial elimination
Argon	Ar	488 to 514 µm	Gated or continuous	Flexible fiber optic, surface contact required	Incision and ablation
Indium gallium ablation, arsenide phosphide gallium arsenide	Diode laser	6.35 to 950µm	Gated or continuous	Flexible fiber optic system, surface contact required	Incision, curettage and bacterial contamination

Table .1 Types of lasers used in Periodontics

APPLICATION OF LASER IN SUBGINGIVAL CALCULUS DETECTION

Lasers has been recently used to detect subgingival calculus. Correct diagnosis of presence and abscence of calculus is important in treatment planning; also complete removal of calculus is essential for proper wound healing.Therefore lasers offer more accurate method of detecting calculus especially when calculus is located in the deepest portionof the pocket.

This method of detection is based on the difference in the fluorescence- emission properties of calculus and dental hard tissues. Fluoroscence detectors of 633- 700nm have been employed for the detection of subgingival periodontopathogenic conditions. Increased value of laser fluorescence is related to presence of calculus and the values decreases after scaling. Application of laser fluorescence is important tool for easy and precise detection of subgingival calculus.

Applications Of Lasers in Non Surgical Periodontal Theapy

Complete removal of bacterial deposits and their toxins from the root surface and within the periodontal pockets cannot be achieved with conventional, mechanical therapy. In addition, access to areas such as furcation, concavities, grooves, and distal sites of molars is limited. Although systemic and local antibiotics are occasionally administered into periodontal pockets for the purpose of disinfection, but with frequent use of antibiotics there is a potential risk of producing resistant microorganisms.

As lasers can achieve excellent tissue ablation with strong bactericidal and detoxification effects, they are one of the most promising new technical modalities for nonsurgical periodontal treatment. Another advantage of lasers is that they can reach sites that conventional mechanical instrumentation cannot. The adjunctive or alternative use of lasers with conventional tools may facilitate treatment, and has the potential to improve healing.

Conventional mechanical treatment usually produces a smear layer and, sometimes, deep grooves on the root surface. A smear layer may adversely affect the healing of periodontal tissues as it contains bacteria and inflammatory substances such as debris of infected cementum and calculus.

Laser irradiation has been reported to exhibit bactericidal and detoxification effects without producing a smear layer.

Gingival curettage after scaling and root planning using mechanical instruments has been shown to have no added benefit over routine scaling and root planing. Therefore, the root surface has been the focus of mechanical debridement, and root surface debridement alone is the main step of nonsurgical periodontal therapy at present. However, the poor clinical outcome of gingival curettage may have been due to the lack of an effective tool for soft tissue debridement.

Contrary to mechanical treatment with conventional instruments, the excellent ablation of tissue with laser treatment is expected to promote healing of periodontal tissues, ablating the inflamed lesions and epithelial lining of the soft tissue wall within periodontal pockets. This procedure might be more effective for the treatment of residual pockets after initial therapy and during maintenance. (Fig .3)

Fig. : Use of laser in subgingival scaling

Part of the laser energy scatters and penetrates during irradiation into periodontal pockets. The attenuated laser at a low energy level might then stimulate the cells of surrounding tissue and periodontal tissue attachment possibly resulting in reduction of the inflammatory condition, and improving the postoperative pain.

Most laser bactericidal studies report a dose/ response relationship; that is, increases in power or energy density result in increased destruction of bacteria. However, in many studies, energy densities are often not reported or cannot be calculated due to incomplete listing of parameters. Studies also vary in how the laser energy is delivered to the target surface, some using a sweeping motion of the delivery tip and others using a static exposure of single or multiple pulses. Lastly, the angle of irradiation can vary from 0 to 90, making computation of energy densities nearly impossible. Despite these problems, one can still discern trends in the literature regarding the bactericidal effects of dental lasers.

Several basic studies have shown the effects of continuous wave CO2 laser irradiation on root surfaces. The continuous wave CO2 laser readily produces carbonization, melting, and cracking of root cementum and dentin. [7]

Misra et al [9]examined the root conditioning effects of the defocus mode CO2 laser after scaling and root planing in vitro. Laser irradiation at 3 W for 1 s completely removed the smear layer with minimal change in the diameter of the dentinal tubules; however, irradiation times of 1.2 and 1.4s produced surface charring and carbonization, and were totally ineffective in exposing the dentinal tubules.

Barone et al [10] investigated the effects of the pulsed defocused mode CO2 laser and fsound that CO2 laser at 2.0 W and 4 Hz with 4.0 mm spot size did not result in any extensive damages to the root surface, root surface was flat and smooth with apparent fusion of the smear layer and concluded that the pulsed defocused mode may present the advantage of decontaminating the root surface.

Crepsi et al [11]reported that the pulsed defocused mode CO2 laser treatment at 2 W and 1 Hz, results in the highest number of tightly attached fibroblasts compared with the nontreated control group and scaling and root planing (SRP) alone and concluded that pulsed defocus mode CO2 laser treatment combined with mechanical instrumentation constitutes a useful tool for root conditioning.

Coffelt et al [12] found that, when CO_2 laser is used at an energy density between 11 and 41 mJ/cm2 in the defocused mode, it destroyes microbial colonies without inflicting undue damage to the root surfaces.

Thus, the CO2 laser, when used with high-energy output, especially in a continuous wave mode, is not appropriate for calculus removal and root surface debridement due to major thermal side-effects, such as carbonization. However, when used with relatively low energy output in a pulsed and/or defocused mode, this laser may have root conditioning, detoxification and bactericidal effects on the contaminated root surfaces.

In 1994, Aoki et al. first documented the ability of the Er:YAG laser to remove subgingival calculus in vitro. They showed that the pulsed Er:YAG laser used with water irrigation was capable of removing subgingival calculus from the root surface effectively at 30 mJ/pulse (energy density of single pulse at the tip: 10.6 J/cm2 per pulse) and 10 Hz, in the contact mode, directed perpendicular to the root surface using a conventional cylindrical contact tip 600 lm in diameter.

In addition, ablation of the tooth substance following laser scaling was generally observed within cementum, with a slight rise in temperature of pulpal side during scaling. Their study suggested the potential for clinical application of the Er:YAG laser in subgingival scaling.[7]

Application of lasers in non osseous surgeries

Soft tissue lasers have been used successfully in many types of periodontal soft tissue surgical procedures. The types of lasers currently available for use on soft tissues focuses primarily on CO2 and Nd:YAG laser energies , both the CO2 and Nd:YAG lasers can be used for frenectomies, ablation of lesions, incisional and excisional biopsies, gingivectomies, gingivoplasties, soft tissue tuberosity reductions, operculum removal, coagulation of graft donor sites, and certain crown lengthening procedures.

The advantages of lasers on soft tissue include a relatively bloodless surgical and post-surgical course, minimal swelling and scarring, coagulation, vaporization, and cutting, minimal or no suturing, reduction in surgical time and in a majority of cases, much less or no post-surgical pain. CO2 lasers, compared to Nd:YAG is faster for most procedures, with less depth of tissue penetration and a well-documented history. [13]

Gingivectomy

In gingival enlargements due to various causes, lasers are use effectively to perform gingivectomies.

For larger hyperplasia's, the carbondioxide wavelength is preferred choice due to its speed. Depending upon the delivery system , tooth protection may be needed. This can be accomplished by placement of a periosteal elevator or wax spatula in the pocket or sulcus. When the laser is used, the beam hits the instrument rather than the tooth, when multiple laser wavelengths are available to the operator, and when teeth are fairly well covered by the tissue the fibre lasers can be used initially to uncover the tooth. A carbondioxide laser can then be used to debulk the larger tissue areas.

With an impending condition of phenytoin hyperplasia, the tissue is usually of uneven bulk, the papillae are bulbous and often freely moveable, all making the gingivectomy more difficult. The gingivectomy does not always provide the desired result. Often there is excessive oozing of blood which is not easily controlled due to the nature of the surgically created wound. Patients often experience postoperative discomfort, and as with any surgical procedure there is always a chance of infection.

The laser gingivectomy appears to offer several advantages over the classic gingivectomy. The laser offers an almost completely dry bloodless field, due to its ability to coagulate blood vessels: The surgical time is also reduced.

Lasers have the ability to coagulate, vaporize or cut by varying the power and the time of application. There is instant sterilization of the area, therefore decreasing the chances of bacteraemia. As it offers noncontact surgery, there is no mechanical trauma to the surgical site. There is prompt healing with minimal postoperative swelling and scarring. Postoperative pain appears to be greatly reduced.

Gingivoplasty

For small tissue aberrations, pseudopockets seen after periodontal surgeries or small areas of reverse architecture with an otherwise healthy periodontium, all of the dental lasers are effective in performing the necessary gingivoplasty.

This is extremely fast procedure, often requiring no local anaesthetic or a topical anaesthetic agent, and they almost always results in no postoperative complications. Carbondioxide lasers are simply used to vaporize the tissue, whereas the fibre lasers are used at various angles to the tissue to create the desired cosmetic results.

Frenectomy

The repositioning or elimination of an aberrant frenum is a procedure extremely well suited to the laser. Surgical time for maxillary midline frenectomies is dramatically reduced because the laser vaporizes the tissue and eliminates the need for sutures and haemostasis. Postoperative pain medications are eliminated in nearly 100% of the cases, and no postoperative scarring is encountered.

Crown lengthening

Lasers are effective for crown lengthening related to excessive soft tissue or in the areas of passive eruptions. When this holds true and patients presents with either clinical crowns that appear too short or an uneven gingival line that produces an uneven smile, this excessive tissue can be removed easily and quickly without the need for blade incisions, flap reflection and suturing.

Coagulation

Lasers are excellent in controlling bleeding for example as in case of coagulation of soft tissue grafting donor sites. For active bleeding sites Nd:YAG and Ho: YAG are the lasers of choice . They are usually used at lower power settings and, if applicable without water spray. In non bleeding sites, to prevent subsequent bleeding all lasers are applicable.

Gingival Depigmentation

The colour of the gingiva is determined by several factors, such as the number and size of blood vessels, epithelial thickness, quantity of keratinisation, and the main pigments within the epithelium which includes melanin, carotene, reducedhaemoglobin and oxyhaemoglobin. Surgical, chemical, cryosurgical and electrosurgical techniques have been used for gingival depigmentation. Recently lasers have been used to ablate cells containing and producing the melanin pigments.

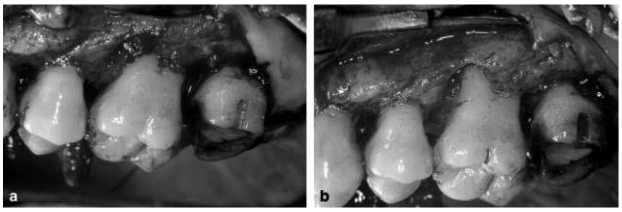
Nd:YAG and argon lasers are reported to be useful in removing gingival pigmentation due to their deep tissue penetrability and selective destruction of the pigmented cells found in the basal cell layers under the epithelium.

Use of lasers in osseous periodontal surgeries

Lasers used in periodontal flap surgeries

Removal of granulation tissue

All the laser wavelengths can be used to remove granulation tissue from periodontal structures or to degranulate any wound site present. In certain areas such as furcation areas, circumferential defects, intrabony defects, or three wall defects, where stubborn tags can persist, laser can be useful aid in helping to degranulate these areas entirely or partially, with subsequent hand instrumentation to complete the process. Caution must be taken not to damage the root surfaces or bone. Nd:YAG lasers with air and water spray appears to offer the greatest advantage for removal of granulation tissue . The fiber tip allows for easy access, and the air and the water spray affords excellent visibility.



Guided Tissue Regeneration

Guided tissue regeneration using surgical membranes generates a new periodontal attachment. One of the goals of membrane use in periodontal surgery is to exclude epithelial downgrowth into the wound. Studies have shown that therapy by guided tissue regeneration does not always exclude all of the epithelium and also surgical membranes are difficult to place, especially when multiple surgical sites are involved.

Research has shown that lasers used to de-epitheliaze surgical flaps may lead to a more predictable and desirable bone and soft tissue results. Furthermore, with this de-epitheliazation, the use of surgical membranes may be eliminated.[14]

Rossman and Israel developed a basic technique for laser use in guided tissue regeneration procedures which includes the use of a CO_2 laser at low power settings to treat the outer aspect of the flap in the area where the GTR membrane has to be placed.

The epithelium is removed from the free gingival margin to the mucogingival junction on both the facial and lingual aspects (palatal) of the flaps. A sweeping motion with the laser, followed by a wipe - down, is used. Next a full thickness flap is raised using a sulcular incisions and mesial vertical releasing incisions, and the appropriate clean out is achieved.

The inner aspect of the flap is debrided with laser to remove any remaining epithelium, and the flap is positioned with interrupted sutures. After the 10 days interval, using the topical anaesthesia, the outer surface of the flap is debrided using the laser under a low power setting to retard epithelial downgrowth during the first 30 days postoperatively

Osseous resection

Erbium lasers also have the ability to perform the osseous resection without raising a flap. Erbium laser has extremely thin tips that may be introduced into the gingival sulcus. These tips may be used to remove the soft tissue at the base of the pocket, expose the osseous crest and perform a very conservative osseous countering to expose healthy tooth structure.

The main advantage of laser osseous surgery compared to the conventional therapies is that there is reduced operative time and Postoperative visits compared with scalpel surgery.

Application of lasers for the treatment of peri-implantitis

Adherent bacterial plaque and calculus develop on the surface of implant abutments, in natural teeth. The maintenance treatment is required to keep the peri-implant tissue healthy in implant therapy. However, mechanical instruments such as metal curettes and ultrasonic scalers are prohibited for decontamination of titanium implant surfaces, since they easily damage the titanium surface.

Recently, lasers have been widely used for soft tissue incision in exposing submerged implants. Lasers may be used for decontamination of implant surface and treatment of peri-implantitis without damaging the implant surface. Regarding the effect of lasers on titanium, the Nd:YAG laser is not suitable for implant therapy, since it easily ablates the titanium irrespective of output energy. However, diode lasers basically do not interact with titanium or the coated material.[7]

Disadvantages and precautions

Lasers may be novel, effective tools for the treatment of periodontitis. However, lasers have disadvantages as well as advantages. Therefore, precautions should be taken when performing laser surgery.

The American Academy of Periodontology suggests several important precautions in the use of lasers. Laser light interacts with target tissues not only in the contact irradiation mode but also in the noncontact irradiation mode. Therefore, inadvertent irradiation to the patient's eyes, throat, and delicate oral tissues outside the target site may occur during treatment and must be prevented.

Particular care must be taken to avoid accidental irradiation to the eyes. The most important precaution in laser surgery is the use of glasses for eye protection. Before laser treatment, protective eyewear, specifically blocking the wavelength of the laser in use, must always be worn by patients, operator, and assistants.

The laser beam may be reflected off shiny metal surfaces of dental instruments, such as retractors or mouth mirrors, which can cause accidental irradiation to adjacent tissues. Use of wet gauze packs may be occasionally useful for protection of the oral tissues surrounding the surgical site from accidental beam impact. Also, adequate high speed evacuation is necessary to capture the laser plume, which is a biohazard Contact with tooth enamel during periodontal treatment should be avoided during CO and Er:YAG laser emission, as they easily cause melting or ablation.[15]

Conclusion

In summary, laser treatment is expected to serve as an alternative or adjunctive to conventional mechanical periodontal treatment. Currently, among the different types of lasers available, Er:YAG laser possess characteristics suitable for dental treatment, due to its dual ability to ablate soft and hard tissues with minimal damage. In addition, its bactericidal effect with elimination of lipopolysaccharides, ability to remove bacterial plaque and calculus, irradiation effect limited to an ultra-thin layer of tissue, faster bone and soft tissue repair, make it a promising tool for periodontal treatment.

References

1. Robert M. Pick. The use of the laser for treatment of gingival diseases Oral Maxillofac Surg Clin North Am. 2004 May;16(2):165-79.
2. Maiman TH. Stimulated optical radiation in ruby. Nature 1960: 187: 493494.
3. J.G. Sulewski, Historical survey of laser dentistry. Dent. Clin. North Am. 2000 Oct;44(4) 717752.
4. Academy of Laser Dentistry 2008 page 1 - 18
5. Robert M. Pick, Bernard C. Pecaro , The Laser Gingivectomy The Use of the CO2 Laser for the Removal of Phenytoin Hyperplasia J Periodontol 1985;56:492-496. ...

6. Robert M. Pick Oral Maxillofac Surg Clinic North Am 1997 feb; 9(1): 1- 18
7. Akira aoki, katia miyuki sasaki, Hisashi watanabe & Isao ishikawa Lasers in nonsurgical periodontal therapy Periodontology 2000, Vol. 36, 2004, 5997
8. Wilder-Smith P, Arrastia AM, Schell MJ, Liaw LH, Grill G, Berns MW. Effect of ND:YAG laser irradiation and root planing on the root surface: structural and thermal effects. J Periodontol 1995: 66:1032-1039
9. Misra V, Mehrotra KK, Dixit J, Maitra SC. Effect of a carbon dioxide laser on periodontally involved root surfaces.J Periodontol 1999: 70: 10461052.
10. Barone A, Covani U, Crepsi R, Romanos GE. Root surface morphological changes after focused versus defocused CO2 laser Irradiation: a scanning electron microscopy analysis. J Periodontol 2002: 73: 370373.
11. Crespi R, Barone A, Covani U, Ciaglia RN, Romanos GE. Effects of CO2 laser treatment on fibroblast attachment toroot surfaces. A scanning electron microscopy analysis. J Periodontol 2002: 73: 13081312.
12. Coffelt DW, Cobb CM, MacNeill S, Rapley JW, Killoy WJ. Determination of energy density threshold for laser ablation of bacteria. An in vitro study. J Clin Periodontol 1997:24: 17.
13. Pick RM and Colvard MD Current status of lasers in soft tissue dental surgery J periodontol 1993 Jul ;64(7):589-602
14. Hom Lay Wang, Jascom Cooke. Dent Clinic N Am 49(2005) 637 - 659
15. Cohen RE, Ammons WF. Lasers in periodontics (Academy report). AAP (The American Academy of Periodontology). The Research, Science and Therapy Committee of the American Academy of Periodontology. J Periodontol 2002: 73: 12311239