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Review Article

DENTAL LASER HAZARDS AND ITS SAFETY PROTOCOLS

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ABSTRACT

The rapid development of laser technology has widened the spectrum of possible applications of lasers in dentistry. Although clinical use of laser systems is increasing, there are still some concerns associated with their use, mainly the hazards and safety measures that need to be taken for all the personnel who might be exposed either deliberately or by accident. This article highlights the risks involved in laser use in dentistry, the safety protocols that need to be followed and the responsibilities of the personnel involved in providing treatment to the patients.

Keywords: Nominal hazard zone (NHZ), Ablation, laser plume, laser safety officer (LSO), Chromophores.

INTRODUCTION

The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Theodore Maiman, a scientist in 1960 developed the first working laser device which emitted a deep red coloured beam from a ruby crystal¹. Dr Leon Goldman, a dermatologist who had been experiment with tattoo removal using ruby laser, focused two pulses of that red light on a tooth of his dentist brother in 1965. The result was painless surface crazing of the enamel. Studies in 1970s and 1980s turned to other devices such as CO₂ and Neodymium Yttrium Aluminium Garnet (Nd:YAG) which were thought to have better interaction with dental hard tissues².

Myers and Myers were the first to receive permission by the US Food and Drug administration to sell a dedicated dental laser Nd:YAG device. Since that time numerous devices are available for use in dental practice and more are being developed³.

Laser uses in dentistry have expanded enormously over the past two decades both in numbers and scope of use⁴. Dental lasers can be separated into three basic groups like soft tissue lasers, hard tissue lasers and laser used in non surgical devices like diagnostic and photo disinfection devices⁵. Soft tissue applications of laser include anterior esthetic gingival recontouring, gingivectomy or gingivoplasty for crown

lengthening procedures, operculectomy, removal of epuli, incisions when laying a flap, incision drainage procedures, frenectomy, vestibuloplasty, coagulation of extraction sites, treatment of recurrent herpetic, aphthous ulcer lesions, uncovering of an implant, pre impression sulcular retraction and ablation of intra osseous dental pathology like abscess or granuloma, removal of benign lesions like fibroma or papilloma on lip, tongue, buccal mucosa and palate⁶. At present, erbium lasers are the only hard tissue laser available commercially. An erbium laser can be used to remove a defective composite restoration, eradicate recurrent decay found underneath and perform any soft/hard tissue crown lengthening that may be necessary, bleaching of vital and non vital tissues, laser etching, laser tooth preparation, laser composite curing. Diagnostic lasers can be used for caries and calculus detection⁷.

There is a basic requirement of the clinician and associated staff to ensure that laser use is carried out within a safe environment. Key to this requirement is an understanding of the device being used, laser physics and adherence to federal, national and international statutes. Laser safety considerations are proportional to established and recognized risk. The potential maximum power output will define a basic approach, but specific to more powerful lasers are measures taken to address additional risks of laser damage to non target oral

tissue, skin and eyes. Such damage may be the result of direct exposure to the laser beam or through the combustion of chemicals, gases and materials used in dentistry. The protection of those personnel involved in laser treatment patient and staff is a prime consideration but it is also important to consider those measures required to safeguard against any risk events⁴.

Laser hazards

Laser devices, regardless of class should be handled with care. With regard to those classes – IIIB and IV – that pose predictable or instantaneous risk, there are dangers associated not only with the laser beam itself, but also arising from the device (electrical, cables, air and/or water supplies) and chemicals either associated with the laser or the ablation of target tissue. The concept of laser beam collimation may be considered theoretical, as in practice most laser beams exiting a delivery system will undergo some divergence with distance. Based on the power output, amount of divergence, beam diameter and configuration, a Nominal Ocular Hazard Distance (NOHD) can be assessed⁸. The possible risk to human tissue is assessed with regard to the Maximum Permissible Exposure (MPE). This is a value of exposure limit above which tissue damage may occur. The MPE value can be applied relative to laser wavelength, power output, beam diameter, possible focusing of the beam, target and non target tissue or structures. Within certain space around a class IV laser, the level of laser radiation that a person is being exposed to is above the MPE. Within this area, called the nominal hazard zone (NHZ) protective measures must be taken⁹.

Eye hazards

Damage from a laser beam may be due to direct exposure of the unprotected eye or diffuse reflection when a reflective instrument directs the beam towards the eye and is present in those situations where wavelength specific protective eyewear is not worn. Damage also depends on the type of laser being used, since a free-running pulsed laser will cause more damage than a continuous laser of equal power. This is because the output power of a free running pulsed laser can achieve high peak power surges in a short pulse followed by long off-time durations. Its peak power is considerably greater than its average output power. For a continuous wave laser, the output power and peak power are the same regardless of whether it is used in a continuous or gated mode¹⁰. In addition the ability of the eyes lens to focus incident light may significantly increase the hazard posed by those wavelengths that may enter the eye¹¹. In current clinical dental use, shorter laser wavelengths (visible to near infrared, 400-1400 nm) being relatively non-absorbed by water, may result in retinal burns in the area of the optic disc. Some visible wavelengths may selectively damage green or red cones in the retina producing colour blindness. In addition wavelengths in 700 – 1400nm range can cause lens damage. The second group of wavelengths, the longer wavelengths (mid to far infrared 1400- 10600 nm) have high absorption in water and corneal, aqueous and lens damage is associated with these wavelengths¹².

Safety protocol for eye hazards

Protection for operator, assistant and patient:

It is mandatory that all personnel within the controlled area of Class IIIB, IIIR and IV laser use should employ suitable eye protection during laser procedures. Measures must be taken to protect the eyes of the staff and patients when the MPE is exceeded. Therefore when the dental laser is on and people are within the NHZ eyewear should be constructed of wavelength-specific material to attenuate the laser energy or to contain the energy within MPE values. The wavelength that the eyewear is specific for must be stamped on glass or side shields. If the eyewear is marked as 810nm – 2890nm, then this means that the eyes exposed to all wavelengths between these two outer limits are protected. Glasses and goggles must cover the entire periorbital region, be free of any surface scratches or damage and be fitted with suitable side panels to prevent diffuse laser beam entry. The protocol for patient is “patient first on and last off.” This means that as soon as the patient is seated in the dental chair, he or she is to put on the appropriate laser eyewear, which is not to be taken off until the patient is leaving the dental operatory at the end of the procedure.

Protection for operator under microscope:

Practitioners using a microscope must fit the appropriate filters and maintain close eye contact with the oculars.

Protection for dental operatory personnel:

The dental operatory personnel must wear the eyewear prior to laser being turned on and not take them off until switched off or put in standby mode. Care must be taken when cleaning laser eyewear and side shields so that their protective coating is not destroyed. The eyewear should be washed with antibacterial soap and dried with a soft cotton cloth in between procedures and patients. Disinfecting solutions generally applied to dental surfaces are too caustic and should be avoided. The eyewear must be inspected frequently to determine whether there is any breakdown (lifting / cracking / flaking) of the protective material that would render the eyewear to be useless¹³.

Non target oral tissue hazards

The laser beam might come in contact with adjacent oral tissues inadvertently during focusing towards the operating field or when the patient moves the head. The close approximation of multiple chromophores in oral tissue (molecular compounds that absorb light or laser energy such as hemoglobin, water, hydroxyl apatite and melanin) demands care during the use of any surgical laser wavelength to avoid unintentional vaporization of other tissues. During any surgical ablation procedure using laser energy, attention is required to focus the beam onto the target tissue and avoid accidentally damaging adjacent tissues. Parallel monitoring of the adjacent tissues by all dental staff present at the time of treatment is to be ensured.

Assistants need to be trained in recognizing adverse or unexpected tissue change as they play a role in monitoring the dental situation, especially if the dentist is using a microscope or other accessory that might reduce the clinician’s wider field of vision¹⁴.

Safety protocol for nontarget oral tissue hazards

Anodized, dull, non reflective, or matte-finished instruments should be employed. Coated (i.e ebonized) instruments should be inspected regularly to ensure integrity of the coating. Glass

mirrors should not be used because they absorb heat from the laser energy and may shatter. Stainless steel or rhodium mirrors may be used safely, providing measures are taken to minimize possible unwanted reflection¹⁵.

Skin hazards

Any potential for damage to the skin through inadvertent exposure to Class IIIB and IV lasers will be relative to the ablation threshold of the skin structure and the incident laser energy. Visible and near-infrared wavelengths (400-1400 nm) have the potential to pass through the epidermis into the superficial and deeper structures respectively. Mid to far-infrared wavelengths (1400-10,600 nm) will interact with surface structures. The governing factor in structural damage is the particular laser wavelength's absorptive potential relative to the tissue elements (chromophores) such as pigment (shorter wavelengths) and water (longer wavelengths) together with the power density value of the laser beam, duration of laser exposure and spot size¹⁶.

Safety protocol for the skin hazards

All those involved in the use of Class IIIB and IV lasers are adequately protected against inadvertent skin exposure. Skin protection can best be achieved through engineering controls. If the potential exists for damaging skin exposure, particularly for ultraviolet lasers (0.200-0.400 μm), then skin covers and or sun-screen creams are recommended. For the hands, gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide the best protection. A laboratory jacket or coat can provide protection for arms. For Class IV lasers, flame-resistant materials may be best.

Chemical hazards

Laser plume poses a significant hazard and occurs as a result of the development of aerosol by product due to laser-tissue interaction. These products can contain particulate organic and inorganic matter including viruses, toxic gases and chemicals. The hazard area for laser generated airborne contaminants (LGACs) may be greater than the laser's identified NHZ. Examples of the products contained in LGAC include human papilloma virus, human immunodeficiency virus(suspected), carbon monoxide, hydrogen cyanide, formaldehyde, benzene, acrolein, bacterial spores and cancer cells. The hazard

presented by the LGACs may include eye irritation, nausea, breathing difficulties, vomiting and chest tightness together with the possibility of transfer of infective bacteria and viruses¹⁷.

Safety protocol for chemical hazards

Regular surgical protective clothing must be employed and specific fine mesh face masks capable of filtering 0.1-micron particles must be worn¹⁸. Use of high-speed evacuation must also be used. It has been determined that for carbon dioxide laser surgery, the evacuation tube should be held as close as 1 cm from the target site; at 2 cm, the evacuation ratio had diminished by 50%¹⁹.

Fire hazards

The high temperatures that are possible in the use of Class IV and certain Class IIIB lasers can themselves either cause ignition of material and gases or promote flash-point ignition. The laser energies used in tissue ablation may surpass the flashpoint of some anesthetic aromatic hydrocarbons used in general anesthesia and the presence of oxygen and nitrous oxide will support a combustion. Many materials that are not normally flammable may burn in an oxygen-enriched atmosphere.

Safety protocol for fire hazards

American national standards institute has allowed gaseous conscious sedation procedures, such as the use of a nosepiece to deliver oxygen and nitrous oxide mixtures to be used during laser operation. However, a closed-circuit delivery system must be used and a scavenging system must be connected to the high-volume evacuation to minimize gas leakage. Within the NHZ, use of aerosols, alcohol-soaked gauze and alcohol based anesthetics are to 'be avoided'²⁰. It is important to request the patient remove any lip products that may contain an oil-based substance that is considered flammable, such as petroleum jelly. Additionally, tissue cleansing or preparation agents that contain alcohol or other flammable chemicals carry specific risk of burning during laser use²¹. If the patient carries an oxygen tank, then the laser should not be utilized for the dental procedure, unless the patient will remain comfortable with the oxygen turned off and the nose cannula removed during the laser portion of the procedure²².

Laser class	Maximum output	Use in dentistry	Possible hazard	Existing Safety measure protocols
Class I Class IM	40 μ Watts (blue) 400 μ Watts (red)	Laser caries detection scanner	No implicit risk Possible risk with magnified beam (class IM)	Blink response Laser safety labels
Class II Class IIM	1.0 milliWatt	Aiming beams Eg. Laser pointers Laser caries detection	Possible risk with direct viewing Significant risk with magnified beam (class IIM)	Slight aversion response Laser safety labels
Class IIIR Class IIIB	Visible 5.0 milliwatts Invisible 2.0 milliWatts 0.5 Watt	Aiming beams Low level lasers Photodynamic antimicrobial chemotherapy devices. Mucosal scanning chemofluorescent devices	Eye damage Eye damage Maximum output may pose slight fire and skin risk.	Safety eyewear Safety personnel Training for class IIIR and IIIB laser users
Class IV	No upper limit	All surgical lasers (Used in dentistry and oral maxillofacial surgery).	Eye and skin damage. Non target tissue damage Fire hazard Plume hazard	Safety eyewear Safety personnel Training and local rules. Possible registration to comply with national regulations

Desirable Laser safety protection protocols	
Access	<ul style="list-style-type: none"> • Rooms with physical barriers walls and one or two access doors – control non authorized access. • Most class IV lasers should have remote inter-lock jack socket, whereby door locks and warning lights can be activated during laser emission. • During laser treatment only clinician, assistant and patient should be allowed within controlled area
Safety officers	<ul style="list-style-type: none"> • Dental practices with class IIIB and IV laser treatment – must appoint a laser protection adviser (LPA) and a laser safety officer (LSO). The LPA is medical physicists who will advice on the protective devices required, MPE and NOHD for any given wavelength being used. Ideally this could be a suitably trained and qualified dental surgery assistant. Duties of LSO include <ul style="list-style-type: none"> ▪ Confirm classification of the laser ▪ Read manufacturer’s instructions concerning installation, use and maintenance of laser equipment ▪ Make sure that laser equipment is properly assembled for use ▪ Train workers in safe use of lasers ▪ Oversee controlled area and limit access ▪ Oversee maintenance protocols for laser equipment ▪ Post appropriate warning signs ▪ Recommend appropriate personal protective equipment such as eyewear and protective clothing ▪ Maintain a log of all laser procedures carried out, relative to each patient, procedures and laser operating parameters ▪ Maintain an adverse effects reporting system ▪ Assume overall control for laser use and interrupt treatment if any safety measure is infringed
Laser safety features	<ul style="list-style-type: none"> • All lasers have in-built safety features that must be cross-matched to allow laser emission. These include: <ul style="list-style-type: none"> ▪ Emergency stop button ▪ Emission port shutters to prevent laser emission until the correct delivery system is attached ▪ Covered foot-switch to prevent accidental operation ▪ Control panel to ensure correct emission parameters ▪ Audible or visual signs of laser emission ▪ Locked unit panels to prevent unauthorized access to internal machinery ▪ Key or password protection ▪ Remote inter-locks
Environment	<ul style="list-style-type: none"> • Nominal ocular hazard distance (NOHD) should be assessed. this is a distance from laser emission, beyond which the tissue (eye) risk is below the MPE. • As with ionizing radiation, the concept of controlled area can be adopted – within which only those personnel involved in laser delivery can enter and with specified protection. The controlled area must be delineated with warning signs that specify the risk, windows, doors and all surfaces should be non reflective and access throughways either supervised or operated by remote interlocks during laser emission • A secure locked designated place for the laser key, if applicable should be assigned together with a designated place for all laser accessories.
Eye protection	<ul style="list-style-type: none"> • All protection glasses or goggles should be marked with the wavelength for which protection is given, together with a value of optical density (OD) • OD refers to ability of a material to reduce laser energy of a specific wavelength to a safe level below the MPE. The OD value should be 5.0 or above for adequate protection
Test firing	<ul style="list-style-type: none"> • Prior to any laser procedure and before admitting the patient, either the clinician or LSO should test the laser, this is to establish that the laser has been assembled correctly, is working correctly and laser emission is occurring through the delivery system • Protective eyewear is worn and all other safety measures met. • The laser directed towards a suitable absorbent material eg: <ul style="list-style-type: none"> ▪ Long wavelengths – water ▪ Short wavelengths – dark coloured paper operated at the lowest power setting for the laser being used, following this the laser is inactivated and the patient admitted.

CONCLUSION

Laser use in dentistry is proven to be beneficial in treating a wide range of dental conditions. Above a range of maximum permitted exposure values, non target tissue is subject to accidental exposure which in the case of the eye, can result in permanent damage. Anyone working with or responsible for potentially hazardous laser equipment should be properly trained in laser safety, be aware of the nature of laser hazards and understand the procedures and safeguards that need to be

implemented, have to establish an adequate safety policy for the management and control of risks arising from the use of laser equipment from various regulatory bodies of laser safety.

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