

Laser Safety in Dentistry: A Position Paper

Laser Safety Committee, Academy of Laser Dentistry

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EDITOR'S NOTE

This is the second of a series of position papers written by the Science and Research Committee of the Academy of Laser Dentistry, on the uses of lasers in dentistry. This paper on laser safety was approved by the Academy's Board of Directors in February 2009. Of course, changes in technology may dictate revision of this manuscript; however, the fundamental principle of the safe use of a laser instrument will remain constant.

Refer to the Glossary on page 62 for explanations of acronyms and definitions of terms.

SUMMARY

Laser use in general dental practice has grown considerably over the past 20 years, both in numbers and scope of use. The registered laser owner is responsible for ensuring that all personnel have a thorough knowledge of laser safety. There exists a duty of care to all dental health care professionals in the application of lasers in clinical practice. Such regulations may exist through federal and/or international standards. The duty of care extends to all staff as well as patients.

General and specific measures must be employed to ensure the safe use of lasers in dentistry.

Laser safety is applicable according to the class of laser being used.

ABSTRACT

In oral health care, the number and range of laser-based technologies have expanded enormously over the past two decades. The scope of this paper is to alert the dental professional to the extent, application, and responsibilities associated with safety when using lasers designed for use in dentistry. By far, the majority of laser instruments are within the private (nonhospital) clinic setting. Laser use extends from those procedures of a diagnostic or nonsurgical (biostimulatory or photochemical) nature, to more powerful devices that are used in surgical procedures. Low-powered lasers may deliver energy of a few millijoules, whereas surgical lasers may have pulsed emission modes capable of peak power delivery in excess of 1,000 Watts. Laser radiation can be dangerous, because it is concentrated and powerful.

This paper draws upon the standards outlined (either explicitly or implicitly with regard to dentistry) by the International Electrotechnical Commission (*IEC 60825-1, Edition 2.0, 2007-03. Safety of laser products – Part 1: Equipment classification and requirements*) and the American National Standards Institute *ANSI Z136.1 – 2007 American National Standard for Safe Use of Lasers* and *ANSI Z136.3 – 2005 American National Standard for the Safe Use of Lasers in Health Care Facilities*.

In addition, interpretation of these standards complements the core of knowledge outlined in the Curriculum Guidelines and Standards for Dental Laser Education that is required by the certification examinations of the Academy of Laser Dentistry.

INTRODUCTION

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. These regulations may apply either specifically to laser use or within broader health and safety legislation.

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 nontarget 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 events.

History can provide us with records of injuries occurring to people due to lasers. The U.S. military, FDA, U.S. Department of Energy, U.K. Medicines and Healthcare Regulatory Agency, and Rockwell Laser Industries, to name a few, maintain logs of laser-related incidents through their device-reporting mechanisms. The following anecdotes provide us with some insight into the extent of injuries and consequences of such accidents. Incidents include lasers that fail to stop after the foot pedal has been released; burns to lips, tongue, and cheeks; firemen entering a surgery in response to a smoke alarm, unaware that a laser was in operation.¹ Other incidents include injuries due to the laser beam being reflected off a droplet.¹ Incidents specific to eyes include an injury because the manufacturer sent the doctor the wrong goggles specific to the laser wavelength being used and the doctor did not double-check the eyewear designation.² Another recorded incident involved a university assistant suing for \$39 million after she sustained a laser eye injury in a laboratory setting. A key factor in her case was that the professors were reported as not adhering to wearing the safety goggles, giving subordinates the impression that the protective eyewear was not necessary. The assistant settled for \$1 million.³ These are just some examples of the nature of laser injuries that can occur, the majority of which can be traced back to poor adherence to established safety protocols.

LASER CLASSIFICATIONS

All lasers used in dentistry are categorized with regard to the potential for damage, extending from Class I lasers, which may pose no implicit risk, to Class IV lasers for which all safety measures are applicable.⁴ Regardless of the class of laser being used, it is advised that one should never look directly into a laser beam, even if it is considered to be “eye-safe.” The classification ascends from Class I through Class IV, with Class I being considered eye-safe and Class IV being the most dangerous. However, with the increased use of magnification devices – loupes and microscopes – there is a potential for laser beams to be magnified and/or focused. Consequently, Class IM and Class IIM contain refinements.

Class IIIR and IIIB lasers are generally low-level instruments, whose wavelengths are in the red part of the electromagnetic spectrum and whose energy range lies between 1 and 500 milliwatts. They require safety personnel to monitor the Nominal Hazard Zone (NHZ), eye protection, and training.

Class IIIR was recognized to include those continuous-wave lasers that may emit up to five times the power of Class I and II lasers.⁵ These lasers pose significant risk of eye damage, and the eyewear must be rated at minimum Optical Density (OD) in the United States (U.S.) or European L6A standard. It is the laser manufacturer’s responsibility to provide the numerical value of the OD, in the operator’s manual, specific to the laser being used.

Table 1 provides an outline of the basic classes of lasers, the delineated emission parameters, examples of uses of each class within dentistry, risks posed to unprotected tissue, and safety measures. For clarification, it should be noted that the blink response is one of the responses that is encompassed within the aversion response. The aversion response consists of blinking and turning one’s head away from the beam path.

Class IV lasers, which are surgical devices, require safety personnel to monitor the NHZ, eye protection, and training. These lasers pose significant risk of damage to eyes, any nontarget tissue, and can produce plume hazards. Plume, in the context of this paper, is defined as the gaseous by-products and debris from laser-tissue interaction. It can have a smoky appearance or be completely invisible to the naked eye. With Class IV lasers, eyewear must be rated at a minimum OD 5. It is the laser manufacturer’s responsibility to ensure that the device class is clearly marked on the laser machine and in certain countries it is required to post such information at all access points to the area in which the laser is being operated. It is the responsibility of the Laser Safety Officer (LSO) to ensure that the safety measures appropriate to each laser class are applied and made known to all staff. It is not the manufacturer’s responsibility to provide the dentist with training in this aspect. However, in the United States, federal regulations require manufacturers to provide certain safety information related to their laser in the laser operator’s manual. The computation, in feet or meters, of the NHZ of the laser is a calculation that is generally beyond the scope of the dentist or LSO. Monitoring and calculating the NHZ are two different issues. It is the manufacturers’ responsibility to calculate what the NHZ distance is and have that information posted in the operator’s manual. It is the LSO’s responsibility to read the manual, ensure that the NHZ around the laser in the dental practice is identified, and personnel adhere to the safety measures.

Table 1: Laser Classification, Power Output, and Risk Analysis⁴

Laser Class	Maximum Output	Use in Dentistry	Possible Hazard	Safety Measures
Class I	40 μWatts (blue)	Laser caries detection	No implicit risk	Blink response
Class IM	400 μWatts (red)	Scanner	Possible risk with magnified beam (Class IM)	Laser safety labels
Class II	1.0 milliWatt	Aiming beams	Possible risk with direct viewing	Sight aversion response
Class IIM		Laser caries detection	Significant risk with magnified beam (Class IIM)	Laser safety labels
Class IIIR	Visible 5.0 milliWatts Invisible 2.0 milliWatts	Aiming beams Low-level lasers	Eye damage Eye damage	Safety eyewear Safety personnel
Class IIIB	0.5 Watt	Photodynamic anti-microbial chemotherapy devices Mucosal scanning chemofluorescent devices	Maximum output may pose slight fire and skin risk	Training for Class IIIR and IIIB lasers
Class IV	No upper limit	All surgical lasers	Eye and skin damage Nontarget tissue damage Fire hazard Plume hazard	Safety eyewear Safety personnel Training and local rules Possible registration to comply with national regulations

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. Laser hazards may be listed as follows:

- Optical
- Nontarget oral tissue
- Skin
- Chemical
- Fire
- Other collective hazards.

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, and beam diameter and configuration, a Nominal Ocular Hazard Distance (NOHD) can be assessed.⁷

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, and target and nontarget tissue or structures.⁸⁻⁹

Within a 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 taken. Many factors determine how large the NHZ area is. For example, an 810-nm diode laser with a maximum power output of 3 Watts will have a different NHZ than another 810-nm diode laser with 5 Watts of maximum output power.

Therefore, it is not correct to say that the NHZ for an 810-nm diode laser is, for example, 8 feet for all diode lasers. The same can also be said for other laser wavelengths; it is incorrect to say that the NHZ for all Er:YAG lasers is 2 feet. The manufacturer has the responsibility of informing the dentist and LSO of the dental laser's specific NHZ by publishing this information in the operator's manual.

EYE HAZARDS

The eye is composed of pigmented and nonpigmented tissue that will absorb incident laser radiation relative to the wavelength being used. Damage from a laser beam may be due to direct exposure of the unprotected eye or diffuse reflection and is ever-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.¹⁰ 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 the peak power are the same, regardless of whether it is used in a continuous or gated mode. In addition, the ability of the eye's lens to focus incident light may significantly increase the hazard posed by those wavelengths that may enter the eye.¹¹ In current clinical dental use, shorter laser wavelengths (visible to near-infrared, 400-1400 nm), being relatively nonabsorbed 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 color blindness. In addition, the 700-1400-nm wavelengths can cause lens damage. The second group of wavelengths, the longer wavelengths (mid- to far-infrared, 1,400-10,600 nm) have high absorption in water, and corneal, aqueous, and lens damage is associated with these wavelengths.¹²

Consequently, it is mandatory that all personnel (clinician, assistant, and patient) 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, i.e., 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. Standards that specify the nature and suitability of laser protective eyewear are contained in ANSI (ANSI Z136.1 – 2007) for North American users, EN 207/208 for European users, and IEC (IEC 60825) for all other regions. The manufacturer's mark must be imprinted on the eyewear. The wavelength or wavelengths that the protective eyewear is specific for must be stamped on the glass or side shields. If the eyewear is marked as 810 nm – 2890 nm, then this means that the eyes exposed to all wavelengths between these two outer limits are protected. If one line states 810 nm and then underneath 2890 nm is stamped, it means that eyes are protected only against these two wavelengths and no protection is provided for wavelengths in between.

In addition, the OD is required to be stamped clearly onto the glass or polycarbonate side frames for North America while references to the OD, CE mark, operation mode (DIR), protective grade (L6A), and Direct Impact Number (DIN) are displayed in Europe.

Please refer to the glossary provided for additional information. Practitioners using loupes must wear the appropriate protective insert or shield. 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. Practitioners using a microscope must fit the appropriate filters and maintain close eye contact with the oculars.

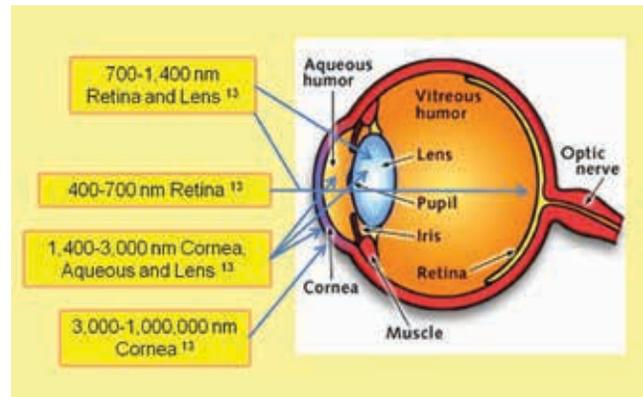


Figure 1: Prime risk structures of the eye at risk vs. laser wavelength (nm). Graphic produced by Dr. Steven Parker.

The protocol for use 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 operator at the end of the procedure. The dental operator personnel must don the eyewear prior to the laser being turned on and not take them off until the laser is switched off or put into 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 useless.

Table 2: Eye and Skin Hazards of Dental Lasers¹³

Lasers	Eye Structure	Eye Damage	Skin
Argon 488-514 nm	Retina	Retinal Lesion	Photosensitive Reactions (400-700 nm) Excessive Dryness Blisters Burns ¹⁴
Caries detection and oral pathology cytofluorescent devices 630-900 nm	See below*	Retinal Lesion	
	Lens (above 700 nm)	Retinal Burn and Cataract (above 700 nm)	
Diode 810-980 nm	Retina	Retinal Burn	
	Lens	Cataract	
Nd:YAG 1064 nm	Retina	Retinal Burn	
	Lens	Cataract	
Ho:YAG 2100 nm	Lens	Cataract	
	Aqueous Humor	Aqueous Flare	
	Cornea	Corneal Burn	
Er,Cr:YSGG 2780 nm	Lens	Cataract	
	Aqueous Humor	Aqueous Flare	
	Cornea	Corneal Burn	
Er:YAG 2940 nm	Lens	Cataract	
	Aqueous Humor	Aqueous Flare	
	Cornea	Corneal Burn	
CO ₂ 10,600 nm	Cornea	Corneal Burn	

* Class I and II caries-detection lasers may become hazardous to the retina when viewed through optical aids, e.g., eye loupes and microscopes, as such magnification instruments can make a diverging beam more hazardous.¹⁵

NONTARGET ORAL TISSUE HAZARDS

The constraints of the oral cavity pose specific risks in access and accidental damage to adjacent or nontarget tissue. The close approximation of multiple chromophores (molecular compounds that absorb light or laser energy such as hemoglobin, water, hydroxyapatite, and melanin in oral tissue)¹⁶ 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. Anodized, dull, nonreflective, or matte-finished instruments should be employed. Coated (i.e., ebonized) instruments should be inspected regularly to ensure integrity of the coating.¹⁷ 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 reflection.

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 vision.

SKIN HAZARDS

Any potential for damage to the skin through inadvertent exposure to Class III B and IV lasers will be relative to the ablation threshold of the skin structure and the incident laser energy. Subablative power levels will pose little threat, other than reversible tissue warming. 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 size.¹⁸⁻²¹ It is important that all those involved in the use of Class III B and IV lasers are adequately protected against inadvertent skin exposure.

CHEMICAL HAZARDS

Laser plume poses a significant hazard²² and occurs as a result of the development of aerosol by-products due to laser-tissue interaction. These products can contain particulate organic and inorganic matter including viruses, toxic gases, and chemicals.

This is not unique to lasers, as it has been known that surgical instruments, such as electrosurgical equipment and dental handpieces, create surgical debris. *American National Standard for the Safe Use of Lasers in Health Care Facilities* states that the hazard area for laser-generated airborne contaminants (LGACs) may be greater than the laser's identified NHZ.²³ 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.²⁴

Of particular importance in restorative dental procedures, other hazardous products may be present in the plume.²⁵ During removal of composite resin with an erbium laser, along with the ejected whole resin particles, small amounts of free methacrylate monomer can be produced. Furthermore, although not an indication for use, directing the erbium laser's energy onto amalgam can produce mercury vapor, according to an *in vitro* study.²⁶ This same precaution also applies to other lasers.

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 viruses.^{24, 27-29} To combat such risk, regular surgical protective clothing must be employed and specific fine-mesh face masks capable of filtering 0.1-micron particles must be worn.³⁰ 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%.³¹

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. ANSI Z136.3 has allowed gaseous conscious sedation procedures, such as the use of a nose piece 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 is to be avoided.³² Consequently, it is important to request that 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 use. 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 procedure.

With general anesthetic procedures, there are three aspects to be considered:

1. Ignition sources (of which lasers are an example)
2. Fuel sources (gauze, drapes, preparation fluids, alcohol, and anesthetic gases)
3. Oxygen-enriched atmosphere (more than 21% oxygen).³³
The laser energies used in tissue ablation may surpass the flash

point of some anesthetic aromatic hydrocarbons used in general anesthesia, and the presence of oxygen and nitrous oxide will support any combustion. Many materials that are not normally flammable may burn in an oxygen-enriched atmosphere.³⁴ Endotracheal tubes need particular consideration to prevent the laser beam from burning a hole in the tube and combusting with the gases. Consequently, the tubes should be resistant to the laser beam and have suitable coating, a wavelength-specific reflective coating if possible, to prevent the possibility of combustion of the material and subsequent airway burns.³⁵ Care should also be taken to prevent the build-up of blood onto endotracheal tubing, as this may lead to an increased fire hazard.³⁶

OTHER HAZARDS

Additional hazards associated with laser use include service and mechanical hazards. Potential service hazards include electrical, water, and air supply lines and cables, as well as connectors and filters. The laser should be serviced regularly according to the manufacturer's recommendations and only by qualified personnel.³⁷ The practitioner should inspect the supply lines and cables, clean and maintain the external portions of the laser, and change necessary filters or other user-serviceable items. In addition, many surgical lasers use a coaxial air or water supply which may be under pressure. No attempt should be made to access internal parts of the machine during use. Capacitors can retain an energy charge, even when the laser is no longer connected to the electrical supply outlet.

Mechanical hazards include moving parts (e.g., articulating arms). Laser machines employ multilevel safety features (fusible plugs, interlocks, pressure relief valves, and warning lights) to inactivate the machine in the event of a component failure. Additional hazards may exist such as heavy articulated-arm delivery systems or the risk of needle-stick injury with fine quartz fiber-optic tips. Care must be taken around the cables and wires associated with the laser, as tripping over and wrenching these cables and fibers can be dangerous. Some machines are portable and, when moved, should be reassembled completely, ensuring stability.

INFECTION CONTROL

In the United States, the Centers for Disease Control and Prevention (CDC) have established infection control guidelines in a 2003 *Morbidity and Mortality Weekly Report*.³⁸ Lasers in dental practices are to be considered as another dental instrument. Dental practitioners and their team must follow standard precautions. Standard precautions include use of personal protective equipment (PPE) (e.g., gloves, masks, protective eyewear or face shield, and gowns) intended to prevent skin and mucous membrane exposures.³⁹

Specific to lasers, any reusable fibers and tips must be heat-sterilized along with their handpieces, and not wiped with a high-level disinfectant. Any debris on the end of the tip must be removed and/or cleaved off the end of the fiber to ensure effective sterilization. The operator's manual should contain recommendations about the sterilization process. For example, it is suggested that one does not sterilize the high-speed, lubricated dental handpieces at the same time as the laser fibers so as to

eliminate the possibility of oil from the handpieces leaking through the bag onto the fibers.³² Disposable tips must be put into sharps containers, along with cleaved pieces of the fiber. Plastic or metal cannulas fitted to the handpiece and used to position the fiber optic should be disposed of in regular trash. Removable or wipeable barriers are recommended to be placed over operational controls on the laser. Care should be shown to the possibility of contamination of all laser hardware; protective sleeves and barriers (e.g., syringe covers, sensor protector sheaths, transparent universal sticky barrier covers) should be utilized where possible. The laser and surfaces within the dental environment should be wiped with high-level disinfectant following the procedure. Any cleaver used on a contaminated fiber should also be heat-sterilized.

ENGINEERING CONTROLS

Through successive internationally agreed regulations, laser devices (specifically but not exclusively Class IIIB and IV) have built-in safety features. These regulations are designed to prevent unauthorized use and protect those involved in laser applications. Engineering controls are set in place by the manufacturer and are always preferred, where possible, over administrative controls. Safety features include the following:

- Locked unit panels to prevent unauthorized access to internal machinery
- Covered foot switch, to prevent accidental operation
- Delayed response from the foot switch (to prevent accidental operation, e.g., unintentional stepping on the foot switch)
- Casters, if present, must be lockable
- Remote interlocks. These constitute a connection between a closed door and the laser. Should the door be opened during laser operation, the remote interlock will shut down the laser
- Key or password protection to prevent the laser from being operated when authorized personnel are not present
- Emission port shutters to prevent laser emission until the correct delivery system is attached
- Emergency stop switch or button – visible and easily located so that the laser can be shut down in an instant without the operator having to go through a lengthy process
- Control panel and display to ensure correct emission parameters are set
- Laser software diagnostics and error messages. Internal systems within the laser that shut down operations when any component that is not functioning correctly is detected
- Specific laser standby and laser-emission modes
- Time-lapsed default to standby mode so that if a laser left in “ready” mode is not used within a certain time frame, the laser will revert to “standby” mode. Stepping on the foot switch in “standby” mode will not initiate the laser to operate
- Audible sound that is distinctive to the laser when it is in operation
- Visible signs on the laser, such as lights which warn whether the laser is in standby mode or is being used.

ADMINISTRATIVE CONTROLS

In addition to the manufacturer’s engineering controls, additional safety measures are also required in order to minimize the risk of an adverse event. In this context, an adverse event is defined a serious and undesirable experience or outcome (including death, life-threatening injury, disability, hospitalization, and intervention to prevent those outcomes) that results from a dental laser marketed in accordance with the standards³² set forth by the regulations governing its use within that specific country or region. It is essential that all surgical lasers be used with responsibility and due regard to their potential safety risk. These administrative policies supplement the aforementioned mechanisms in order to facilitate a safe laser environment and require the appointment of a Laser Safety Officer (LSO) to oversee their implementation. Policies include:

- Establishing written Standard Operating Procedures (SOPs) for the dental practice, as required by ANSI Z136.1 – 2007 and other national standards as they may apply
- The appointment of an LSO with specific responsibilities, as follows:
 - Serves as the “keeper of the key” to secure the key in a safe place when the laser is not in operation
 - Authorized to shut down laser operation. This authority is to be recognized and respected in the dental office regardless of the dental employee position held by the LSO
 - Keeps current with safety standards, such as OSHA, ANSI, IEC (or those of the appropriate country) through educational meetings and literature review, and updates this information with the dental practice
 - Supervises the education and training of the dental team
 - Assists with evaluation when a new laser is needed
 - Understands the operational characteristics of the laser(s) in the practice
 - Using the manufacturer’s NHZ, identifies this area within the dental office in accordance with the laser being used
 - Ensures correct warning signs are posted at every entryway into the operatory in which the laser is being used
 - Ensures that the laser signs are taken down after the procedure is completed, and not left up as “wallpaper”
 - Oversees the protective eyewear
 - Ensures the correct wavelength-specific eyewear is being worn within the NOHD
 - Ensures that the policy of patient eyewear “first-on and last-off” is adhered to. The policy for the dental team is “on before the laser is initiated and off after the laser application is finished,” and the laser is turned off or placed in standby mode
 - Ensures the laser is being operated by authorized personnel only
 - Understands the operational characteristics of the laser(s)
 - Knows the output limitations of the device
 - Determines the controlled area and the potential hazard and nonhazard zones

- Ensures laser maintenance, beam alignment, and calibration is familiar with the biological and other potential hazards of the laser
- Supervises medical surveillance and incident reporting
- Keeps a log of recorded laser use and parameters employed
- Ensures proper test-firing of the laser prior to admission of the patient into the operatory.

Laser test-firing is a safety measure designed to establish that the laser is working correctly and that there is patency of the delivery system. Test-firing should be carried out by the clinician or LSO prior to every procedure and before the patient is admitted to the controlled area. Protective eyewear is worn and all other safety measures met. The laser is directed toward a suitable absorbent material (e.g., water for longer wavelengths – 1400-11,000 nm, and dark-colored paper for short wavelengths – 400-1400 nm) and operated at the lowest power setting for the laser being used. Test-firing will demonstrate that the laser is functioning properly, all connections are securely in place, the delivery system is not damaged, and the laser beam is patent.

It is necessary to define a controlled area, within which all safety aspects pertaining to laser use are enforced. The LSO must follow the operator's manual regarding the dimensions or limits of the controlled area. Dental clinics with multichair, open-plan environments need to address the physical dimensions and administrations of their controlled area in greater detail. Within the controlled area, all surfaces should be nonreflective, and measures should be taken to ensure that all supply cables for the laser along with its delicate delivery system are protected from inadvertent damage. A fire extinguisher should be sited for easy access.

The LSO is required to oversee the training of the entire dental team with regard to lasers, including the nonuser and administrative staff. It is imperative that nonuser team members in the dental office are educated at some level with regard to the laser equipment and have received training on aspects of laser safety as they apply to their dental office. Regulatory agencies recognize the essential nature of appropriate training in laser use⁴⁰⁻⁴³ and there is an implied necessity that clinicians should receive training as part of their duty of care and dental licensing.

The Standard Operating Procedure is a living, written document that outlines the existence and identity of laser devices within a given practice setting, personnel authorized to use the laser, and safety measures to address the hazards associated with the lasers in that particular dental practice. It contains all the local and national rules, including those set out in the aforementioned administrative controls. In the United States, ANSI Z136.1 – 2007 requires every dental practice with a laser to have such a document and many countries or regions have similar requirements.

The Academy of Laser Dentistry adopted the Curriculum Guidelines and Standards for Dental Laser Education which defines a core of knowledge appropriate to the safe use of lasers in dentistry. All those clinicians passing proficiency examinations with the Academy will satisfy an acceptable level of competence in laser safety, and nonclinicians may take proficiency examinations to be recognized as laser safety officers.

CONCLUSION

Laser use in dentistry is proven to be beneficial in treating a wide range of dental conditions as well as a therapeutic tool in tissue management. The dynamics of laser energy beams pose general risks to non-oral tissues and the immediate environment of such use must be deemed at risk from direct or scattered exposure. Safety measures have been devised to safeguard those personnel – staff and patients – who may be involved in dental treatment using lasers. Most safety measures are the product of official regulatory bodies such as ANSI, OSHA, FDA, and IEC, but additional measures may be the product of individual needs within particular dental offices and consequently recorded in local rules. The reader is encouraged to consult these regulatory bodies as they may apply on a national or regional basis, to ensure a correct and responsible compliance with all laser safety measures in the treatment of dental patients. The analysis of general and specific risk during laser use has been addressed through many statutory instruments and all clinical procedures should be measured against such standards, in order to offer the maximum protection for the patient, clinical staff, and those within the immediate environment.

GLOSSARY

ANSI: American National Standards Institute. A not-for-profit organization, founded in 1918, that oversees the administration and coordination of the United States private sector voluntary standardization system.

OSHA: Occupational Safety and Health Administration. A division of the U.S. Department of Labor, OSHA serves to ensure safety and health in the workplace. Created in 1971.

FDA: The U.S. Food and Drug Administration, a division of the U.S. Department of Health and Human Services. Founded through consolidation in 1930. The FDA enacts the provisions of the Federal Food, Drug and Cosmetic Act (rev. 2004). The FDA Center for Devices and Radiological Health (CDRH) is responsible for the premarket approval of all medical devices, as well as overseeing the manufacturing, performance and safety of these devices.

IEC: International Electrotechnical Commission. Founded in 1906, the IEC is a not-for-profit, nongovernmental international organization that prepares and publishes international standards for all electrical, electronic, and related technologies. The headquarters are in Geneva, Switzerland.

NHZ: Nominal Hazard Zone. This is the space within which the Maximum Permissible Exposure (MPE) is being exceeded.

MPE: Maximum Permissible Exposure. This represents a value of exposure to laser energy above which a risk of target damage may occur. MPE values are applied to the unprotected eye and skin.

OD: Optical Density. The ability of the glass or polycarbonate shield to attenuate the laser beam. The opacity of the protective filter.⁶

NOHD: Nominal Ocular Hazard Distance. That distance from the emission port of the laser beyond which any exposure is within MPE values.

DIR: Ability of the glass or polycarbonate to attenuate the beam relative to the emission mode of the laser for which the eyewear is intended, using coding "D" (continuous mode), "I" (pulsed mode), "R" (Q-switched mode).

L6A: Defines the suitability for the eyewear within clinical, industrial, or research conditions.

DIN: Direct Impact Number. A standard for the glass or polycarbonate shield against beam damage, relative to a 10-sec exposure (continuous wave) or 100 pulses (free-running pulsed emission mode).

CE Mark: "Conformité Européenne" license approved for distribution and use within the European Community CE Marking Directive (93/68/EEC) 1993.

Critical Instrument: Any instrument that penetrates soft tissue, contacts bone, enters into or contacts the bloodstream, or other normally sterile tissue. Examples include surgical instruments, periodontal scalars, and scalpel blades.³⁸

Semi-critical Instrument: Any instrument that does not penetrate soft tissue, contact bone, bloodstream, or sterile tissue but can contact mucous membranes. Although dental handpieces are considered semi-critical, the U.S. Centers for Disease Control and Prevention state that they should be heat-sterilized and not high-level disinfected.³⁸

High-Level Disinfection: Process that inactivates vegetative bacteria, mycobacteria, fungi, and viruses but not high numbers of bacterial spores.³⁹

Sterilization: Use of a physical or chemical procedure to destroy all microorganisms including substantial numbers of resistant bacterial spores.³⁹

FURTHER READING

Further reading is recommended in order to ensure that the clinician is complying with national, federal, or regional regulations:

ANSI Z136.1 – 2007 American national standard for safe use of lasers. Published by the Laser Institute of America (LIA). Contact: Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, Florida 32826 USA, www.laserinstitute.org

OSHA (USA). *Guidelines for laser safety and hazard assessment (STD 01-05-001-PUB 8-1.7)*. U.S. Department of Labor – Occupational Safety and Health Administration. Contact: www.osha.gov.

International Electrotechnical Commission (IEC).

A wide range of publications relating to laser use and safety. Contact: www.iec.ch.

Laser Institute of America. *CLSOs' best practices in laser safety*. 1st ed. Laser Institute of America 2008. ISBN 978-0-912035-90-1 Contact: Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, Florida 32826 USA, www.laserinstitute.org.

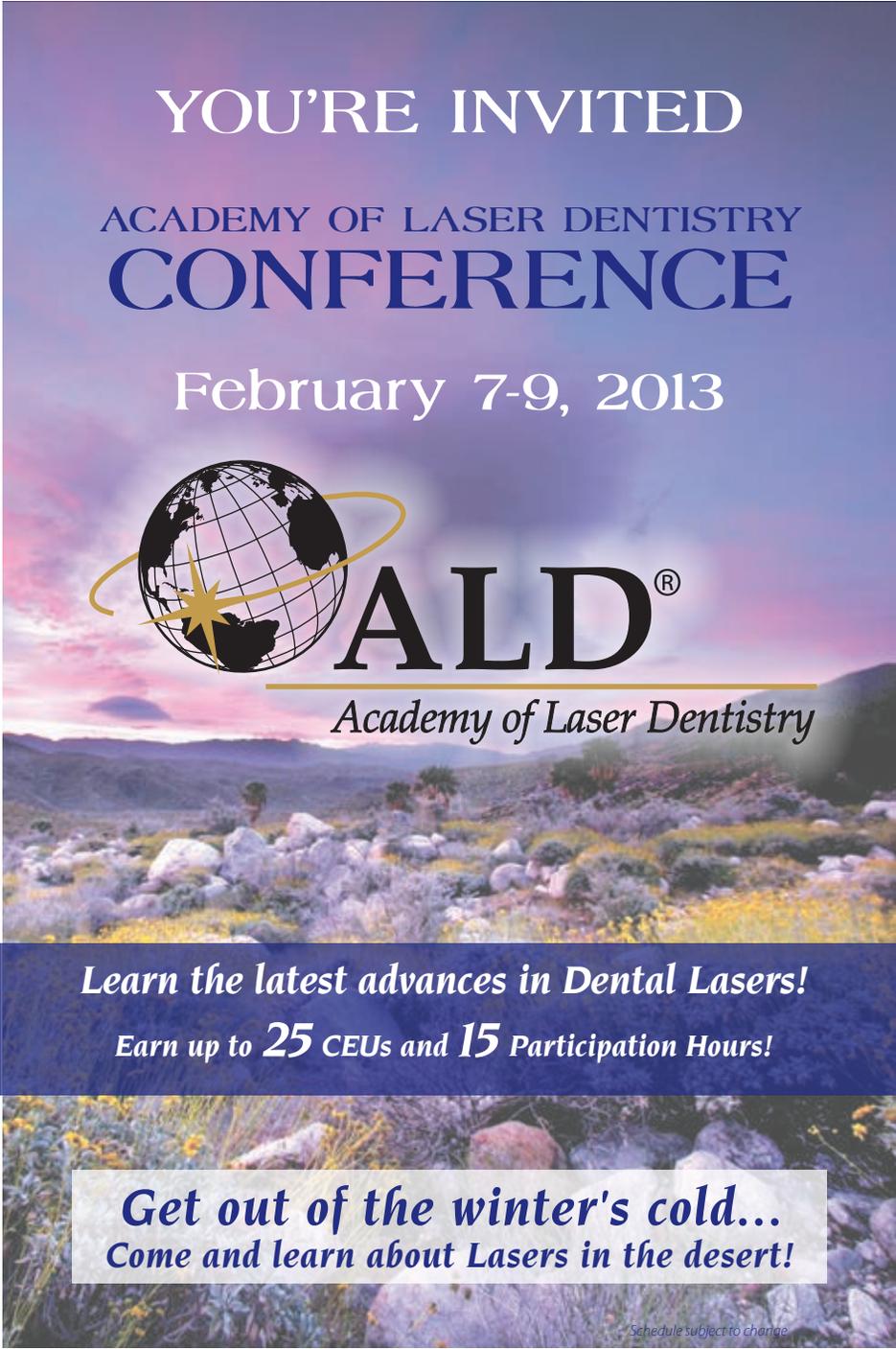
MHRA (UK). *Device bulletin. Guidance on the safe use of lasers, intense light source systems and LEDs in medical, surgical, dental and aesthetic practices*. DB2008(03)April 2008. Contact: Medicines and Healthcare products Regulatory Agency, 1 Nine Elms Lane, London SW8 5NQ United Kingdom, www.mhra.gov.uk.

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