Review Article

Dental Lasers: A Review of Safety Essentials

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Abstract:

The laser technology offers a wide range of uses in dentistry with certain advantages to the general dental practitioner like bloodless surgery, minimal post-operative pain, reduction of operative time and high patient acceptance. Patient acceptance has also been demonstrated in various studies. Apart of these major advantages, safety regarding the use of lasers cannot be neglected and has become an important concern in this modern era of dentistry, as application of this technology is growing day by day. Potential hazards can be encountered while using lasers like ocular hazards, tissue injury, inhaling the vapor emitted by the laser procedure, fire and explosion hazards etc. The safe use of lasers includes all the individuals who might be exposed either deliberately or accidently while using lasers and effective measures that can be undertaken by clinicians and health professionals to minimize the injuries caused due to laser accidents. The present article serves to explore the risks involved in the use of lasers in dentistry and suggest some of the laser safety protocols/measures that can be established in the dental office for prevention of laser injuries.
Keywords: laser; safety; hazards; dentistry; measures

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Introduction

Light has been used as a therapeutic agent for many centuries. In ancient Greece, sunlight was used in “heliotherapy”, or the exposure of body to the sun for the restoration of health. The Chinese also used sunlight to treat conditions such as rickets, skin cancer and even psychosis. This use of light for treatment of various pathologies is referred to as ‘Phototherapy’ (1). Around 1400 B.C. Indians used a drug called *“psoraleus”* to treat vitiligo. A lotion of this drug was applied to the skin, which was then exposed to sun. Egyptians also used the same psoraleus to treat leukoderma (2).

The dental lasers of today have benefited from decades of laser research and have revolutionized several areas of treatment in the last three & a half decades of the 20th century. The interaction of laser radiation on soft tissue enables dry and bloodless surgery, minimal postoperative swelling and scarring, and minimal postoperative pain (3). Lasers for hard tissues encourage efficient diagnosis of caries and improve the resistance of dental enamel to caries, laser etching of enamel, cavity preparations, photopolymerization of composite resin and sterilization of the root canal system (4-6).

Safe use of lasers is also one of the important concerns in the use of laser therapy. With the availability, utilization and future development of different laser wavelengths and methods of pulsing, much interest is developing in this growing field (7). Diodes, Neodymium-Doped Yttrium Aluminium

Garnet (Nd: YAG), Erbium and Carbon Dioxide Laser (CO_2) lasers are Class 4 lasers, which are considered high-powered dental lasers. They are a hazard to eyes and skin and require special precautions. Although many regulations and standards relating to laser safety are in effect, there continue to be an average of 35 laser injuries per year in U.S. (8). This can be attributed to unmonitored use of lasers in many solo practices. Furthermore, the level of training and experience of dental staff is generally far less than that of the laser surgical nurse or hospital laser safety officer (9). Therefore, the present review article focuses on the various hazards that can be encountered by the patients and the dentist while using laser and control measures that can be adopted to minimize the injuries caused by the same.

Laser Hazard Classification

A hazard is something with the potential to cause injury. There are a number of hazards associated with laser use in a clinical environment, the most obvious being the laser light itself. Accidental exposure could be caused by a misaligned or misdirected laser beam, laser light escaping from the protective housing of the unit, or a broken or detached optical fiber. There are various international laser standards and classifications. The Centre for Devices and Radiological Health (CDRH) of Food and Drug Administration (FDA) of USA sets forth the standards governing the manufacture of lasers in the Code of Federal Regulations (CFR) (10). This standard categorizes all laser devices into one of the four classes based on their total energy output and wavelength. The laser used in dentistry generally fall into the class IV category, which is considered the most hazardous group of lasers (Table 1).

Another classification is set by the 'The International Electrotechnical Commission' (IEC), a global organization that prepares and publishes international standards for all electrical, electronic and related technologies (Table 2) (11).

The Laser Institute of America, which serves as a secretariat for the American National Standard Institute (ANSI), has developed both general and clinical standards that currently serve as voluntary guidelines for the safe use of lasers in dentistry and medicine (12). In addition to ANSI, detailed guidelines have been published by Occupational Safety and Health Administration (OSHA). The types of hazards that may be encountered within the clinical practice of dentistry may be grouped as in Table 3.

1. Ocular Hazards

Potential injury to the eye can occur either by direct emission from laser or from the reflection from

Table 1. Classification of Lasers and associated hazards

Class	Description
I	Low powered; safe to view
II a	Low powered; visible; cannot produce any known eye or skin injury during operation based on a maximum exposure time of 1000 seconds.
II b	Low powered; visible; incapable of emitting laser radiation at levels that are known to cause skin or eye injury within the time period of the human eye aversion response (0.25 seconds).
III a	Medium powered; visible; harmful if viewed less than 0.25 sec without magnifying optics.
III b	Medium powered; hazardous if viewed directly.
IV	High powered (> 0.5W); ocular, skin and fire hazards. (eg. lasers used in dentistry)

Table 2. Classification of Lasers (IEC Standards)

Class	Description
I	Very low risk; "safe under reasonably foreseeable use"
I M	Wavelengths between 302.5 nm and 4000 nm, and are safe except when used with optical aids (e.g. binoculars).
II	Do not permit human access to exposure levels beyond the Class 2 AEL (Accessible Emission Limit) for wavelengths between 400 nm and 700 nm.
II M	Have wavelengths between 400 nm and 700 nm, and are potentially hazardous when viewed with an optical instrument.
III R	Range from 302.5 nm and 106 nm, and is potentially hazardous but the risk is lower than that of Class IIIB lasers.
III B	Normally hazardous under direct beam viewing conditions, but are normally safe when viewing diffuse reflections.
IV	Hazardous under both intra beam and diffuse reflection viewing conditions. They may cause also skin injuries and are potential fire hazards.

Table 3. Various hazards encountered in dentistry

	Laser Hazards Encountered in Dentistry
1.	Ocular Hazards
2.	Tissue Damage
3.	Respiratory Hazards/Environmental Hazards
4.	Combustion Hazards (Fire and Explosion)
5.	Electrical Hazards (Shock)

mirror like surfaces. Dental instruments have been capable of producing reflections that may result in tissue damage to both the operator and the patient. The use of carbonized or non-reflective instruments has been recommended during laser treatment (12). Several structures of the eye may be injured as a result of laser emissions. The site of injury is directly dependent on the preferential absorption of various wavelengths by specific structures of the eye. The primary ocular injury that may result from a laser accident is a retinal or corneal burn. Retinal injury is possible with emissions in the visible and near infrared spectral regions. Even low intensity beams can cause damage because of the focusing effect of the lens and cornea. Approximately 95% of the incident radiation entering the eye is absorbed by pigmented epithelium of the retina and choroids layer. Irreversible retinal burns resulting in permanent blindness can occur by conversion of incident radiation to heat energy within a fraction of a second. Other potential ocular injuries from various wavelengths may occur e.g., injury to the sclera, aqueous humor, cataract etc (13).

2. Tissue Damage

Laser induced damage to the skin and other non-target tissue (oral tissue) can result from thermal interaction of radiant energy with tissue proteins. Temperature elevations of 21ºC above normal body temperature (37ºC) can produce cell destruction by denaturation of cellular enzymes and structural proteins, which interrupts basic metabolic processes (13). Histologically, the thermal effect of absorbed radiant energy is manifested as thermal coagulation necrosis for wavelengths above 400 nm. Other non-thermal tissue interactions are thought to induce injury through photochemical and photo acoustic mechanisms. They occur with single or repetitive pulses of very soft duration. Although they have been no reports of laser-induced carcinogenesis to date, the potential for mutagenic changes have been questioned. Of clinical significance is the potential damage to deeper tissue from penetration of specific wavelengths such as the continuous wave Nd: YAG laser. With prolonged exposures of low power density from this type of laser, excess thermal necrosis that may not be apparent at the tissue surface can occur (14).

3. Respiratory/Environmental Hazards

Another class of hazards involves the potential inhalation of air borne biohazard: materials may be released as a result of surgical application of lasers. These secondary hazards belong to a group of ‘potential laser hazards’ (also called as ‘non beam hazards’). They do not pertain to injuries resulting from direct exposure to laser beam. Inhaled air borne contaminants can be emitted in the form of smoke or plume generated through the thermal interaction of surgical lasers through tissue or through the accidental escape of toxic chemical and gases from the laser itself (15). Toxic gases and chemicals are a more common hazard in dental research facilities and laboratories. Some of the toxic gases and chemicals are: fluorine, hydrochloride gases, toxic dyes and solvent.

A study by the National Institute for Occupational Safety and Health (NIOSH) evaluated the air that Operating Room personnel were exposed to during laser procedures and found that detectable levels of ethanol, isopropanol, anthracene, formaldehyde, cyanide and airborne mutagenic particles were found. Inhalations of these toxic aerosols have been found to be potentially damaging to the respiratory system (16, 17).

4. Combustion Hazards

In the presence of flammable materials, laser may pose other significant hazards. Flammable solids, liquids and gases used within the dental surgical setting can be easily ignited if exposed to the laser beam. Toxic fumes released as a result of combustion of flammable materials present an additional hazard (18, 19). The use of flame resistant materials and other precaution is therefore recommended. Some of the common flammable materials found in the dental treatment areas are:

- Solids: clothing, paper products, plastic, waxes and resins.
- Liquids: ethanol, acetone, methylmethacrylate, solvents.
- Gases: oxygen, nitrous oxide, general anesthetics, aromatic vapors.

5. Electrical Hazards

Most laser systems involve high potential, high current electrical supplies. The most serious accidents with lasers have been electrocutions. There are several associated hazards that may be potentially lethal (20). Electrical hazards are grouped as:

- Shock hazards
- Fire hazards or explosion hazards

Safe manufacturing practices offer adequate protection from these hazards. Insulation, shielding, grounding and housing of high voltage electrical components provide adequate protection under most circumstances from electrical injury. Installation and servicing of laser equipment should always be performed by qualified personnel and not by the dentist. It is a good practice to have at least two persons in an area while working on high energy power systems. In labs where laser power supplies are opened or serviced by lab personnel, dental and other auxiliary staff should be trained in cardiopulmonary resuscitation (21).

Laser Hazard Control Measures

According to OSHA guidelines and ANSI standards, for the safe use of lasers in dentistry, control measures are required to reduce the possibility of unwanted exposure of patient and personnel to laser radiation (22). Four categories of control measures are:

1. Engineering controls
2. Personal protective equipment
3. Administrative and procedural controls
4. Environmental controls

1. Engineering Controls

Engineering controls are normally designed and built into the laser equipment to provide safety. Engineering controls such as enclosures, interlocks and beam stops are very effective at eliminating hazards (if not defeated). Some of the important engineering controls recommended by the ANSI are as follows (23).

- Protective Housing: A laser shall have an enclosure around it that limits access to the laser beam or radiation at or below the applicable Maximum Permissible Exposure (MPE) level. A protective housing is required for all classes of lasers except, of course, at the beam aperture.
- Master Switch Control: All Class IV lasers (including dental lasers) and laser systems require a master switch control. The switch can be operated by a key or computer code. When disabled (key or code removed), the laser cannot be operated.
- Optical Viewing System Safety: Interlocks, filters, or attenuators are to be incorporated in conjunction with beam shutters when optical viewing systems such as telescopes, microscopes, viewing ports, or screens are used to view the beam or beam-reflection area.
- Beam Stop or Attenuator: Class IV lasers require a permanently attached beam stop or attenuator which can reduce the output emission to a level at or below the appropriate MPE level when the laser system is on 'standby'.
- Laser Activation Warning System: An audible tone or bell and/or visual warning (such as a flashing light) are recommended as an area control for Class III b laser operation. Such a warning system is mandatory for Class IV lasers.

2. Personal protective equipment

All people within the dental treatment room must wear adequate eye protection, including the patient. When selecting the protective eyewear, several factors should be considered. They are as follows (22).

1. Wavelength of laser emission
2. Maximum permissible exposure limits
3. Degradation of absorbing media or filter
4. Optical density of the eyewear
5. Radiant exposure limits
6. Need for corrective lenses
7. Multiple wavelength requirements
8. Restriction of peripheral vision
9. Comfort and fit

Optical density is one of the most important factors to consider when choosing laser eye protection. The attenuation should be to reduce the beam exposure to the eye to relatively safe levels. Laser protective eyewear is intended to provide a level of protection that may be used to stare directly into the beam. Eyewear must comply with The Personal Protective Equipment at Work Regulations SI 1992/2966 (HMSO 1992) and the British Standard BS EN 207:2009 (BSI 2010) (24).

3. Administrative and procedural controls

If general anesthesia is administered during any dental procedure, in place of the standard P.V.C intubation tube, a red rubber or silastic tube should be used. For further protection, the tube can be wrapped with 1/3-1/2 inch aluminium tape. Highly reflective instruments and those with mirrored surfaces should be avoided since they cause damage to the non-target tissues (13). A wax spatula or periosteal elevator can be inserted into the gingival sulcus to serve as an effective shield when lasing soft tissue near teeth (25).

For most applications it may be advisable to use low power time settings initially before progressing to higher and faster times. When lasers are not actually been used for treatment or if long pauses occur between use, the unit should be placed in a standby mode to prevent inadvertent firing of the laser beam. Most manufacturers provide a cover or metal hood to prevent accidental activation of the laser beam. The foot switch should be cleaned and inspected prior to use to avoid getting stuck in a position while operating. Most laser accidents and injuries can be prevented if appropriate control measures are recognized and implemented (12).

4. Environmental controls

Evaluation of environmental hazards involves an assessment of three primary aspects of the laser treatment area that should be considered to establish adequate control measures for the particular application (12). These include:

a) Physical environment in which the laser is used

Laser use should be confined to controlled areas with restricted access. Use of protective laser curtains should be considered to prevent accidental exposures to passers-by. Fail-safe mechanisms that prohibit the laser from firing when doors are opened are also useful to prevent accidental exposure to persons entering the operating room during laser procedures (26, 28). All entrances to the operating theatre should be clearly marked with a removable warning signs that contains the words 'Danger' and 'Laser Radiation.' Highly reflective instruments and surfaces should be avoided to prevent reflection of the laser beam onto the non-target tissues.

b) Potential for injury attributed to direct exposure from the laser beam output and delivery mechanism.

To avoid an electrical hazard during the operation of the laser unit, the floor of the operating room must be kept dry. Because laser energy generates heat, care must be taken to avoid the use of flammable and explosive liquid or gases in the operating room. Flammable materials such as surgical drapes and gauze sponges may be soaked in sterile saline to reduce the potential of burning by accidental exposure to the laser beam (26).

c) Level of training and knowledge of laser safety of the persons

All staff members should receive objective and recognized training in the safety aspects of laser use within dentistry, as with other specialties (27). The ANSI Z136.1 standard states that the management (employer) has the fundamental responsibility for the assurance of the safe use of lasers owned and/or operated by the employer (23). There are three main types of training programs-

- Laser Safety Awareness
- Laser Safety Refresher
- Laser Safety Update

Role of Laser Safety Officer (LSO)

The Laser Safety Officer (LSO) is an individual designated to be responsible for a laser or system of lasers and for the preparation and enforcement of a safety plan, including standard operating procedures for the safe operation of lasers. The LSO has the authority and responsibility to monitor and enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser hazards (10). Dental practices offering Class IIIb and IV laser treatment, must appoint a laser protection advisor (LPA) and a LSO. The LPA is usually a medical physicist who will advise on the protective devices required, MPE and nominal ocular hazard distance (NOHD) for any given wavelength being used. The LSO is appointed to ensure that all safety aspects of laser use are identified and enforced. Ideally, this could be a suitably trained and qualified dental surgery assistant (9, 28). According to ANSI, the LSO and other employees routinely working with or around lasers are strongly recommended to participate in laser safety training programmes.

Conclusion and Recommendations

Medicine has entered the 21st century, an era of high technology. The dental laser offers the dentist not only the window, but also a door into this high tech area. At present, only very few applications of laser treatment have become well accepted methods. Safety regarding the use of lasers is not optional. It should be the highest priority of all staff members involved in the surgical procedure. There should be a concerted effort to better educate physicians, provide more educational support for perioperative staff members, and conduct additional research to improve equipment and ancillary supplies. Prevention of accidents requires thorough knowledge of their causes and the application of measures to avoid them. Based on the hazards encountered due to lasers (medicine and dental) and various control measures that can be undertaken to prevent injuries, the following recommendation are put forth (29,30).

1) All class IV lasers (most hazardous lasers) should be considered potentially hazardous to anyone present during the time their operation.
2) It is strongly advised that any safety precautions delineated by the manufacturer in the operator's manual and general safety precautions listed within the ANSI and OSHA standards should be strictly followed.
3) Prior to any clinical or research application of a laser, the intended operator of the laser system must have a thorough knowledge of the operation and safety requirements of the specific laser system and should have received hands-on instruction related to its practical application.
4) All the staff or other personnel present within the laser operating field should be well versed in the general safety practices applicable to the laser operation.

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