Laser safety in dental practice in the United Kingdom

Steven Parker*[1] and Mark Cronshaw[1]

Key points

- The safe use of lasers in UK dental practice has been the subject of evolving regulation during the past 35 years.
- Currently, the adjunctive use of Class IIIB and IV lasers in dental practice is subject to regulatory overview by the Care Quality Commission in England and similar devolved authorities in other UK nations.
- It is the responsibility of the clinician to notify the regulatory authority as to laser use.
- The appointment of a laser protection adviser is mandated, to provide guidance as to the practice's environment suitability, responsibility and role of the laser safety officer, and development of inclusive local rules.

Abstract

Laser technology has become a mainstay of dental practice, ranging from scanning and diagnostics to antibacterial photonics, photobiomodulation and surgical dental, osseous and soft tissue ablation. The phenomenon of incident photonic energy interaction with target oral and dental tissue may be seen as variable, according to light wavelength choice and its match with tissue absorbance, but fundamentally providing outcomes as a product of the beam power and photon concentration. Inasmuch as the clinician may control the degree of laser-tissue interaction, there exists a risk of unwanted or unplanned outcome from poorly managed laser power levels. Possibly of greater risk is the danger of exposure of unprotected non-target tissue, skin and eyes to laser photonic energy, applicable to the patient and attending dental staff. Awareness of such risks, relative to a given laser power output, prompts adherence to regulation and guidelines as to use. Overriding regulations covering laser use are issued by the International Electrotechnical Commission and these are devolved through regional and national adoption for implementation. The scope of this paper is to guide the clinician and supporting staff to understand the reasons for regulation and guidelines and to detail the nature and scope of compliance in the United Kingdom when using laser technology.

Background

This paper draws upon an earlier publication in the British Dental Journal,[1] with emphasis on the changing legislation and evolution of laser technology, wavelengths and application in dentistry.

The first laser appeared in 1960 and was a Ruby (633 nm) laser accredited to T. H. Maiman. The prime source of regulation of such an invention would fall to two bodies of influence: the International Electrotechnical Commission (IEC) and the American National Standards Institute (ANSI). The IEC is responsible for the international governance of standards relating to electronic technologies, including those within medicine. ANSI, originally established as the American Engineering Standards Committee, in 1926, hosted the conference that created the International Standards Association (ISA), an organisation that would eventually become the International Organization for Standardization. Through successive initiatives of common interest, ANSI adopted its present name and is affiliated with the IEC.[2]

Notwithstanding the common interest in defining regulations on all aspects of laser technology and safety, the two bodies have developed an individual series of publications which have been adopted in general to reflect commercial or geographical outreach, either in favour of the United States or alternative regions, especially continental Europe. Each set of regulations are annotated as either IEC or ANSI and are listed as a summary in Table 1.

[1]Leicester School of Pharmacy, De Montfort University, Gateway House, Leicester, LE1 9BH, UK.
*Correspondence to: Steven Parker
Email address: thewholetooth@mail.com

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Laser classification

In 1974, the IEC created Technical Committee 76 to address standards relating to lasers, with a particular focus on safety. This committee developed the four-class (I–IV) system for lasers that was amended in the light of technical development and application in 2002 to form a global classification reference. This classification is listed in Table 2.

Laser classification provides an ascending grouping by laser emission criteria (wavelength, output power limits), as this may pose a risk to unprotected tissue exposed to such emission.[3,4] The individual classes reference upper limits of power output, expressed as accessible emission limit (AEL) and such power limits relative to a maximum permitted exposure (MPE) value for the unprotected eye.[5] Each class is summarised as follows:

- Class I/Class IM – this class of lasers of visible (400–700 nm) wavelength are safe under all operating conditions and as such there is no risk to unprotected eyes or skin. This means the MPE cannot be exceeded when viewing a laser with the naked eye. Class IM lasers are not hazardous under normal operating conditions but may be so if viewed with operating loupes or microscope. Given the nominal higher photonic energy of shorter

Table 1 Published regulations and guidance instruments pertaining to the safe use of lasers as may impact on dentistry. The IEC and ANSI instruments provide an essential mirror of regulations. Devolved administration of IEC instruments relate to British (BS) and European (EN) standards

IEC (BS EN) regulation instrument	Area of influence	ANSI regulation instrument	Area of influence
IEC (BS EN) 60825-1:2014+A11:2021	Laser classification. Laser safety measures	ANSI Z136.1-2014	• Hazard classification and calculations • Criteria for eye and skin exposure measurements • Education and organisation and implementation of employee laser safety training programmes
IEC/TR 60825-8: 2006	Guidelines for the safe use of laser beams on humans	ANSI Z136.3-2018	• Guidance for the testing and labelling of laser protective equipment • Emphasis is given to ensuring adequate testing of laser protective eyewear • Determine the wavelength(s) of laser protection • Determine the pulse duration: continuous wave (CW), FRP, Q-switched, etc
IEC TR 60825-14:2004	Guidance on best practice in the safe use of laser products that conform to IEC 60825-1	ANSI Z136.4-2021	• Recommended practice for laser safety measurements for hazard evaluation
IEC (BS EN) 60601-2-22:2020	Safety requirements and essential performance of surgical, cosmetic, therapeutic, and diagnostic laser equipment	ANSI Z136.7-2020	• The safe use of lasers in health care • Laser safety programmes/LSO in healthcare • Lasers used in medicine and surgery • Sample policies and procedures/local rules
BS EN 207:2017	Personal eye-protection equipment. Filters and eye-protectors against laser radiation		
BS EN 208:2009	Standard for specification for personal eye-protectors used for adjustment work on visible lasers only (ie 400–700 nm wavelength range)		
Medicines and Healthcare products Regulatory Agency UK (MHRA)	Lasers, intense light source systems and LEDs – guidance for safe use in medical, surgical, dental and aesthetic practices		

visible wavelengths, the AEL of Class I and Class IM lasers must not exceed 40 µW (blue) or 400 µW (red)

- Class IC – under IEC 60825:2014, a new Class IC is defined where these lasers are designed explicitly for contact application to the skin or non-ocular tissue.[6] During operation, the laser, by design engineering and shielding, should not pose a risk to the,[46] unprotected eye
- Class II/Class IIM – a Class II laser's AEL is limited to 1 mW continuous wave. Emission applies to visible-light lasers (400–700 nm) and is safe because the blink reflex will limit the exposure to no more than 0.25 seconds.[7] Inasmuch as Class II laser beams pose a manageable hazard, with the adjunctive use of optical magnification, including operating loupes and microscopes, the risk of wavelength-related tissue damage increases, prompting the need for additional precaution, including eye protection. Such potential prompts the suffix 'M'
- Class IIIR – although the MPE of the unprotected eye may be marginally exceeded, the risk is low. A Class IIIR laser (R = relaxed) may be considered safe with restricted beam viewing.[8] This class tier may relate to low power continuous-wave (CW) emission (<5 mW) visible wavelengths (400–700 nm) and the expansion in such laser technology within visible spectrum wavelengths. Where other wavelengths or pulsed emission devices are considered, the upper limit of five times the emission of a Class II laser may apply. Class IIIR lasers do not pose a risk of fire or eye damage through diffuse beam reflection[9]
- Class IIIB – unprotected eye and skin exposure to Class IIIB lasers should be deemed a significant hazard, prompting operator training and suitable safety protocols. With Class IIIB lasers of wavelength emission range 300 nm UV (ultraviolet) to far infra-red, the AEL associated with CW mode is ≥500 mW, but this is significantly reduced for pulsed, visible (400–700 nm) emission output, to 30 mW. Operator training and protective eyewear are typically required with the use of Class IIIB lasers. Additionally, these lasers must be equipped with a key switch and a safety interlock
- Class IV – this is the highest-class tier and represents those laser sources whose AEL exceeds 500 mW output power, and the AEL of Class IIIB lasers. With ascending output power, the risks pertaining to unprotected skin, eyes and other non-target tissue are high, resulting in wavelength-specific thermal or structural damage. Operational protocols are mandated to include training in use for operator and assistant, appropriate eyewear, risk assessment and local rules – the latter to include warning signage and restricted access to treatment areas where such lasers may be used. Class IV lasers may pose a fire risk with flammable materials, liquids and gases and these risks may equally apply with reflected beam exposure. In the United Kingdom (UK), those adopted regulations and statutes relating to non-ionising radiation use in

Table 2 Laser classification to reflect ascending levels of maximal power output, use of optical magnification or specific application

Laser classification 2002+							
I	IM	IC	II	IIM	IIIR	IIIB	IV

dentistry, Class IIIB and Class IV lasers mandate the registration of such units, together with appropriate supportive training and operational protocols.[10] Comparatives outlining risk versus laser class are summarised in Figure 1.

Laser safety hazards

Laser photonics and enhanced risk profile

The emission beam of a laser has two intrinsic properties compared to 'natural' light: for a given laser, the beam wavelength is unique and of a single value, a property known as monochromatic. This property will influence the degree of positive interaction with a target tissue and its constituent absorptive tissue elements or chromophores. Additionally, the sinusoidal wave progression of the laser emission is spatially and temporally coherent in that each wave is in phase compared to the mixture of light waves in, for example, a multiwavelength incandescent light emission.[11]

Such unique properties, of significance in the application of a chosen wavelength as an adjunct to a chosen procedure, also enhances the risk profile.[12] The unprotected eye is at considerable risk of damage from all dental laser wavelengths in the range of wavelengths 445–10,600 nm, but as represented in Figure 2, those visible and near infra-red wavelengths that may be focused to the retina, represent massive photonic density (irradiance) and devastating outcome.[13]

Laser beam risks

Optical risks

Within a wide range of recorded laser-related accidents, extending to include healthcare, industry, laboratory research and military purposes, operator error is cited as a significant causative contributor.[14] Research relating to accidents (by implication involving laser wavelengths) found in dentistry broadly identify two groups that potentially may adversely affect occular function and structure.[15] Wavelengths from 400–1,400 nm (visible and near-infrared) with high absorption in pigmented tissue components can pass through the transparent structures at the front of the eye and impact on the retina (Figure 3). Conversely, mid- to far-infrared wavelengths (2,780–10,600 nm) and their greater absorbance in tissue water and hydroxyl groups will interact with the cornea.

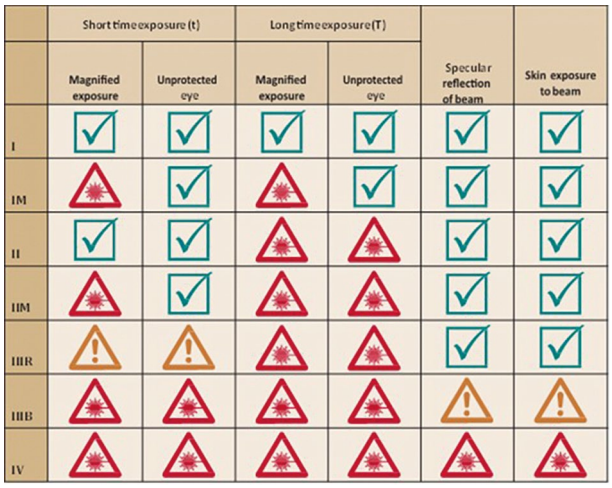

Fig. 1 Risk analysis relative to tissue and laser class. 't' and 'T' relate to short and prolonged eye exposure (normal and magnified). Other risk groups consider reflected (specular) beam and non-occular (skin) tissue. 'Tick' indicates safe use, '!' suggests caution and 'laser symbol' denotes danger. Reproduced from S. Parker, 'Laser regulation and safety in general dental practice', *British Dental Journal*, vol 202, pp 523–532, 2007, Springer Nature

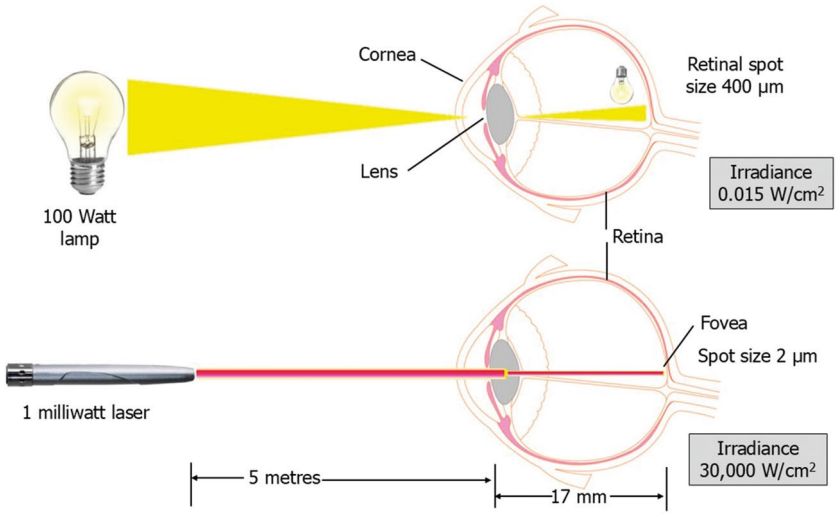

Fig. 2 A comparison of the potential risk to the unprotected eye, posed by coherent visible/near infra-red light. Appropriate, adequate eye protection is mandated when using all Class IIIB and Class IV lasers

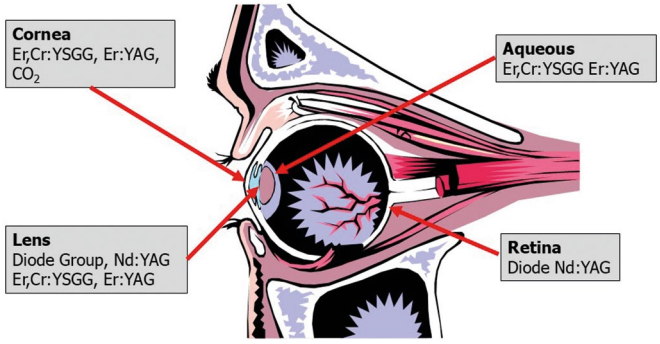

Fig. 3 Overview of areas of potential occular tissue damage versus laser wavelengths used in clinical dentistry

Retinal damage arising from supra-MPE irradiation is invariably a more serious event, in both damage and scope for repair.[16] Incident light focusing onto vital sensory tissue of the retina renders the outcome of exposure to the destruction of visual perception elements or even whole tissue areas. Visible wavelength damage may result in colour blindness and possibly the absence of pain receptors in the retina may add to the extent of damage associated with those invisible near infra-red wavelengths found with dental lasers.[17]

Longer wavelengths with anterior compartment interaction may cause damage through ablation, scarring and distortion of vision (Figure 3).[18]

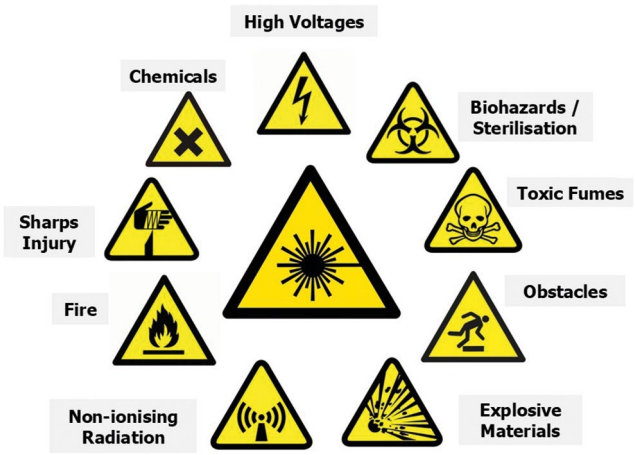

Fig. 4 Schematic representation of risk associated with non-beam laser hazards in dentistry

Skin risks

Peri-oral skin may be at risk as a result of an excessive target dose applied to anatomical lesions that are amenable to laser-adjunctive therapy. The shorter wavelengths used in dentistry are longer than the UV (<400 nm) spectrum and their photonic energy is insufficient to ionise cellular DNA (deoxyribonucleic acid); as such, they cannot potentiate a mutagenic, pre-cancerous change. However, these, along with other 'dental' wavelengths, may pose a risk of erythema, keratitis and so-called 'skin burns'.[19,20] Whether a target or non-target, peri-oral and lower facial skin irradiation must address the risk profile of exposure to coherent laser energy.

Laser plume

Surgical ablation of both soft and hard oral tissue will give rise to products of laser-tissue interaction, collectively termed 'laser plume'. Laser-assisted caries removal and all soft-tissue surgery may give rise to a mixture of water vapour, gaseous hydrocarbons, carbon monoxide and dioxide, and particulate organic material (including bacteria and viral bodies). Plume inhalation can be serious and may cause breathing difficulties, nausea and consequent infection through inhalation of bacteria.[21,22,23] The plume arising from mid-infrared wavelength ablation of dental hard tissue may contain tooth fragmental products of laser spallation; risk profiles may be considered similar to that posed by the debris that is produced with an air turbine.[24] The significant rise in small particle contaminants (particulate matter [PM]) and volatile organic compounds (VOC) associated with laser plume production during dental laser use has been the subject of investigation. Correspondingly, to address the rise in PM (2.510 µm) and VOC levels and associated risk to personal health, physical ventilation of the controlled area is considered very important, regardless of the wavelength and clinical procedure.[25,26]

All laser-assisted tissue ablation risks from plume production should mandate the wearing of appropriate oral masks or facial screen by both clinician and assistant, and gloves and high-speed suction aspiration must be used to control the spread of all ablation products.[23]

Non-beam risks associated with laser use

Regulations to address the safe use of lasers include consideration of non-beam risks associated with Class IV laser use. Malfunction or misuse may give rise to hazards associated with mains (electricity, pressurised air, water) supply and associated cabling should be free from defect or traffic flow. Additionally, the use of low flash-point gases and liquids (eg alcohol wipes and disinfectants) should be used with caution in relation to laser irradiation.[27,28,29] Figure 4 provides a summary of non-beam risks associated with laser use in dentistry.

UK Class IIIB and Class IV laser registration

Coexisting UK statutes

Acts of Parliament that may impact high-power emission laser use for clinical dental professionals are included in Table 3.

The need for strict guidelines and regulation to include the registration of surgical laser use is considered to be both logical and appropriate in view of the potential for everyday hazards surrounding use, together with appreciable risk. The adoption of regulations and associated guidelines should be seen as supportive of a 'best practice' approach to the safe delivery of laser therapy, rather than punitive directives that impede or inhibit the integration of lasers into clinical dentistry. Additionally, the structure of such regulations should be specific to the integration of lasers in dentistry and dental practice, in order to avoid reference to other areas of laser use that might compromise and limit the ready adoption among clinical professionals in dental practice. Through a period of over 30 years, attempts have been made to rationalise laser use in clinical dentistry with over-riding regulation. From times that at first seemed monolithic, overburdening and contributing to clandestine laser use, the current level of responsibility for dental professionals is to comply with a streamlined approach to regulate proportionately – a modality that must recognise potential risk for the patient and operator. In terms of direct requirements pertaining to the use of Class IIIB/IV lasers in dentistry (in treating 'disease, disorder or injury'), there is a mandatory obligation on the part of the intended registered practice and devolved clinical and support staff, to register with the Care Quality Commission (CQC).[28] The CQC regulates against the Health and Social Care Act 2008 (Regulated Activities), Regulations 2010 and the CQC (Registration) Regulations 2009 and that dental practices are providing services that are safe, effective, caring, responsive and well-led.

Across the UK, laser registration and regulations as to use, are devolved as follows:

- England – to comply with the CQC's Fundamental Standard on Premises and Facilities, within the scope of the Health and Social Care Act (Regulated Activities) Regulations 2014[30]
- Scotland – as Healthcare Improvement Scotland[31]
- Wales – as the Independent Healthcare Services[32]
- Northern Ireland – as the Health and Social Care Regulation and Quality Improvement Authority.[33]

In general, permission to practise dentistry requires the applicant (registered manager) to meet standards of services, outlined in a Statement of Purpose that is made at the time of original registration. The use of Class IIIB/IV lasers in dentistry requires additional registration with the CQC, using the statutory notification about change to a Statement of Purpose[34] (CQC [Registration] Regulations 2009, Regulation 12[3]).

Within the auspices of a practice inspection, the CQC will consider how such laser equipment is used when reviewing if the practice is safe. A number of regulation areas (Reg.) may be implicated with possible reference to lasers and laser use. These are listed in Table 4.

Specific regulations that are considered with regard to laser use are: 'cleanliness and infection control, safe care and treatment' (Reg. 12) and 'suitability of premises and equipment' (Reg. 15).

The following is taken from the overview of CQC regulations in relation to the governance of the provision of dental care services:

- Reg. 12: safe care and treatment – 'providers must assess the risks to people's health and safety during any care or treatment and make sure that staff have the qualifications, competence, skills and experience to keep people safe. Providers must make sure that the premises and any equipment used is safe and where applicable, available in sufficient quantities. Providers must prevent and control the spread of infection. Where the responsibility for care and treatment is shared, care planning must be timely to maintain people's health, safety and welfare'
- Reg. 15: premises and equipment – 'to make sure that the premises where care and treatment are delivered are clean, suitable for the intended purpose, maintained and, where required, appropriately located, and that the equipment that is used to deliver care and treatment is clean, suitable for the intended purpose, maintained, stored securely and used properly'.[30]

Table 3 Prime statute instruments against which Class IIIB/IV laser use may be regulated

UK Act of Parliament	Actual/implication for Class IIIB/IV laser
The Dentists Act 1984	• General Dental Council's *Scope of practice/Standards for the dental team* • Defining those personnel licenced to use lasers adjunctive to the practise of dentistry
Health and Safety at Work Act 1974	Legal UK framework for the management of health, safety and welfare of all people within the workplace including patients
The Control of Artificial Optical Radiation at Work Regulations 2010	All optical radiation devices, including lasers and intense pulsed light systems, LEDs and other diagnostic and therapeutic light sources, used in medical, surgical, dental or aesthetic practices
Control of Substances Hazardous to Health Regulations 2004	Applicable to the dyes used in some lasers, the gas used as laser coolants and the material contained in the laser/IPL-generated smoke plume
Provision and Use of Work Equipment Regulations 2008	Maintenance logs for all equipment should be held and kept up to date. Instructions on safe operation, hazard assessment and contingency plans adopted
Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013	As applicable to adjunctive laser use
The Health and Social Care Act 2008	CQC (2010)/HSCA (Regulated Activities) Regulations 2014. Subordinated to member countries of the UK
The Medicines and Healthcare products Regulatory Agency	• The Medical Devices Directive (Directive 93/68/EEC [CE marking]) • Directive 98/79/EC on *in vitro* diagnostic medical devices • *Lasers, intense light source systems and LEDs – guidance for safe use in medical, surgical, dental and aesthetic practices*

Table 4 CQC regulations that may be areas where safe and appropriate laser use are assessed

CQC regulation	Area of governance that may impact Class IIIB/IV laser use in dentistry
Reg. 9	Care and welfare of people who use services
Reg. 10	Assessing/monitoring the quality-of-service provision
Reg. 11	Safeguarding people who use services from abuse
Reg. 16	Safety and availability of equipment
Reg. 17	Respecting and involving people who use services
Reg. 18	Consent to care and treatment
Reg. 19	Complaints
Reg. 20	Records
Reg. 21	Requirements relating to workers
Reg. 22	Staffing
Reg. 23	Supporting staff

Evolving CQC interpretation of compliance relative to laser use involves so-called quality statements – 'safe', 'effective', 'caring', 'responsive', 'well-led' – and a key line of enquiry (KLOE): 'how do systems, processes and practices keep people safe and safeguarded from abuse?'.[30]

Aspects of this KLOE are considered under the following areas:

- Staffing – the mandatory appointment of both a laser protection advisor (LPA) and a laser safety supervisor (LSS). The latter may be referred to a laser safety officer (LSO), in line with ANSI 136.3-2018 (American National Standard for Safe Use of Lasers). All staff involved in using lasers must be trained. This should be updated regularly. Staff training should include

evidence of laser-specific knowledge, course attendance, certification, etc
- Controlled area – only use lasers within a designated controlled treatment area. Only people directly involved in treating patients with lasers should enter. Clear warning signs must be displayed showing that lasers are being used. Everyone in the area, including the patient, must wear appropriate eye protection during laser emission
- Management – there must be a governance framework in place for the safe use of lasers that includes: risk assessment; local rules for safe use; a maintenance schedule for equipment with inspections by a competent person; a quality assurance system for staff to check equipment (for example, daily or weekly); and a system to report critical incidents, including contact details of secondary specialist ophthalmic referral and professional indemnifier
- Health and safety – safety protection equipment for staff and patients must be provided. Health surveillance to be available for employees if their skin or eyes are affected by laser use. Fire prevention measures.

The appointed LPA will be able to provide an overall assessment of the premises and the equipment being used, together with applicable templates relating to risk assessment, treatment protocols, local rules and point of contact in the event of evolving circumstances relating to laser use in the practice. Each aspect of compliance must be available in hard copy to allow all responsible members of staff to sign and retain a copy.

The full compliance should be reviewed on a timely basis and certainly in the event of any staff changes/additions, or the acquisition of additional lasers and changes/additions to the laser treatment-controlled area.

Laser safety measures

Environment

Laser beam divergence over distance can only be controlled through the use of correcting lenses. Most dental lasers will deliver a 'spot' size relative to the delivery handpiece or delivery tip and the spot diameter will increase as the tip-to-tissue distance increases. Beam divergence will cause a reduction in photon concentration (power density or beam irradiance). Accepting the power output, amount of divergence and beam diameter and configuration, a nominal ocular hazard distance can be assessed.[35] This is a distance from the laser emission, beyond which the tissue (eye) risk falls below a level of potential damage, known as the MPE. This is a complex calculation that can be done by a LPA, but for a Class IV dental laser with divergent beam, this distance is approximately 3 metres. Consequently, as with ionising radiation, the concept of a controlled area can be adopted, within which only those personnel directly involved in laser delivery can enter and with specified protection.[36,37,38] The controlled area must be delineated with warning signs that specify the risk; accessed throughways either supervised or operated by remote inter-locks during laser emission; all surfaces should be non-reflective; and windows should be assessed for hazard through beam transmission and covered as required. If applicable, a secure, locked, designated place for the laser key should be assigned, together with a designated place for all laser accessories. In addition, a suitable fire extinguisher should be sited for easy access.

Training

All staff members should receive objective and recognised training in the safety aspects of laser use within dentistry, as with other specialties.[39]

UK laser safety officers

With reference to CQC registration, dental practices offering Class IIIB and IV laser treatment must appoint an LPA and an LSS/LSO.[30]

The LPA is defined through the Medicines and Healthcare products Regulatory Agency (MHRA) 2015 Laser Guidelines[40] as 'the LPA should be knowledgeable in the evaluation of laser hazards and should have responsibility for advising on their control'. In general, the LPA should be certificated through one of two organisations:
- The Association of Laser Safety Professionals[41]
- RPA 2000 – certifying competence in ionising and non-ionising radiation protection practice.[42]

LPA support for a Class IIIB/IV laser registrant may include the following:
- Planning advice on the introduction of a laser in a dental practice setting
- Defining the laser treatment-controlled area
- Provide risk assessments related to the use of the laser
- Provide a treatment protocol to govern the use of the laser in the delivery of therapy, including a review of typical safe operating parameters
- Provide advice as to protection measures and eyewear specification
- Drawing up, distribution and enforcement of local rules for all relevant staff
- Ensure appointment of an LSS/LSO
- Ensure safety training for all relevant clinical staff
- Oversee post-installation commissioning of the laser
- Ensure liaison with all relevant persons and regulatory authorities in the event of any significant laser-related adverse events
- Undertake periodic review of all aspects of laser safety governance to maintain contemporary compliance with laser safety regulations.

The LSS/LSO could be a suitably trained and qualified dental surgery assistant, owing to the demands for on-site contribution to laser safety during treatment. Duties of the safety supervisor are summarised in Table 5.

Table 5 Laser safety supervisor/officer in-practice duties

LSS/LSO standing duties	LSS/LSO active (in use) duties
• Read the manufacturer's instructions concerning installation and use of the laser equipment • Confirm the class of the laser • Be familiar with and oversee maintenance protocols for laser equipment • Train other staff in the safe use of lasers • Maintain an adverse effects reporting system.	• Define the controlled area • Post appropriate warning signs • Recommend appropriate personal protective equipment, such as eye wear and protective clothing • Set up the laser and ensure all connections are sound and positive • Inspect delivery system • Test fire laser • Assume overall control for laser use and interrupt treatment if any safety measure is infringed • Maintain a log of all laser procedures carried out, relative to each patient, the procedure and laser-operating parameters.

Laser safety features

All lasers have in-built safety features that must be functionally cross-matched to allow laser emission (Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9, Fig. 10, Fig. 11). With reference to IEC (BS EN) 60825-1,[43] these should include:

- Locked unit outer panels to prevent unauthorised access to internal machinery
- Key or password protection – a majority of current laser units will operate a digital coding
- (Optional) remote inter-lock facility to prevent access to the controlled area during laser emission
- Emission port shutters to prevent laser emission until the correct delivery system is attached
- Control panel to ensure correct emission parameters and provide visual reference to error coding
- Covered footswitch to prevent accidental operation; Bluetooth interface to avoid cabling
- Audible or visual signs of laser emission
- 'Stand by' mode in the event of a timed non-emission
- Emergency 'stop' button
- Laser software diagnostics and error messages.

Fig. 5 Numeric key to operation

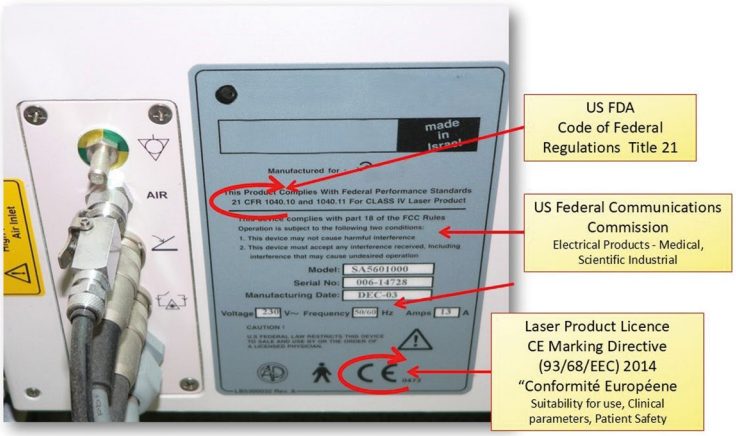

Fig. 6 Backplate, with conformity coding references

Fig. 7 Emission wavelengths – wavelength, emission mode and maximum power. Coaxial aiming beam is also referenced

Eye protection

During laser use, all persons within the controlled area must wear appropriate eye protection. This will be authorised by the LSO to ensure wavelength-specific eyewear that covers the entire periorbital area and is free of scratches or structural damage.[44]

Laser safety eyewear appropriate for use in the provision of laser dentistry must conform to current regulation under BS EN 207 and receive compliance through the CE (Conformité Européenne; UK Conformity Assessment [UK CA] equivalent) being clearly marked. The purpose of protective eyewear is to reduce the level of irradiance to that below an MPE value for the unprotected eye and power attenuation represented logarithmically as an expression of optical density (OD).[45]

The OD value should be 4.0 or above, representing a minimum 10,000 times attenuation for adequate protection. In addition, other metrics are necessary and these are:

- Direct impact values – this measurement of eyewear suitability relates to protection according to laser use. In conditions appropriate to those in clinical laser dentistry, there should be capacity for the eyewear to effectively attenuate accidental beam exposure equivalent to 10 seconds (CW emission) and 100 pulses (free-running pulsed emission). The scale of protection should be >5
- Protective standards – protective laser eyewear should carry specific labelling to define:
  - OD
  - L operation mode (research/industrial/clinical)
  - Wavelength (nm) – either single value or a specified range

Fig. 8 Covered footswitch

Fig. 9 Emergency STOP button to abort laser emission

Fig. 10 Mains electrical/air/water

- Manufacturer's mark
- DIR (doing it right) standard (D – CW; I – pulsed; R – Q-switched delivery modes)
- CE/UK CA.[46]

An example of what should appear on a pair of correctly prescribed protective glasses is shown in Figure 12.

Test firing

It is essential to the appropriate safe use of the laser that the machine is in working order and laser emission is operating correctly. The LSO should oversee a test fire of the laser prior to the patient attending and within the controlled area.[47] With all safety measures applied, including suitable eyewear, the laser is operated using the lowest power settings and with coaxial (air/water) services activated. The beam is directed away from the operator and into a suitable absorptive material (water for longer, mid and far infra-red wavelengths and dark coloured articulation paper for short wavelengths); through this procedure, the patency of laser delivery may be confirmed. Test fire objectives and procedures are listed in Table 6.

Local rules

Practice local rules as applicable to the safe use of lasers in dentistry may be viewed as similar to those applied to the use of ionising radiographic equipment. They should be inclusive and applicable for interpretation by all staff members involved in the delivery of laser-assisted therapy. The appointed LPA should assist and confirm the drawing up and periodic re-review of this document, and should include the following:

- Registered name and postal address of the practice where the laser will be used
- Class IIIB and IV laser(s) being used, identified by manufacturer, wavelength, emission mode, power output, delivery system and serial number (as applicable)
- All personnel authorised to use the laser and their associated role
- Training and education of all authorised personnel
- All those designated an LSS/LSO and declaration of appropriate training
- Controlled area designation and access
- Duties of LSS/LSO to include knowledge of equipment set-up/use/set-down, treatment protocols and operating parameters

- Operation of equipment, including schedules of inspection and maintenance
- Adverse effects policy, including accident reporting, investigation, analysis and remedial action.

The local rules should be read and signed by all practice personnel involved in delivery of laser treatment and should be updated regularly.[40]

Regulation of non-monochromatic and non-coherent photonic sources

Intense pulsed light (IPL) therapy uses a bandwidth photonic emission, commonly found in dermatological and beauty therapy clinics. Thermal conversion of incident light may be employed in the treatment of hair removal, skin blemishes and associated cosmetic procedures. There is a mixed opinion as to regulation of such devices[48,49] and the MHRA makes representation as to the services of an LPA to fully assess the risk profile; although, the availability of such technology within dental practice has not fully tested the need for such overview.

Perhaps of greater influence is the emerging development of photonic devices, using bandwidth, non-coherent light sources or light-emitting diode (LEDs). The basis of such growth derives from positive effects of photobiomodulation in the adjunctive treatment of pathology, wound/post-surgery support and post chemotherapy and radiotherapy oral mucositis. Published data have emphasised the risks associated with glare and unprotected eyes, together with possible photochemical change, a risk posed by the use of shorter blue LED devices.[50]

As this area of therapy develops, greater clarity may emerge as to the significance of associated hazards and measures to address any level of risk.

Conclusion

Laser use in dentistry has increased both in use and sophistication. There exists an acceptance of hazards posed by laser energy, sufficient to create risks of significant and possible permanent (target and non-target) tissue damage. To this effect, an ascending classification exists to identify the maximum power capacity of a given laser, with those assigned as Class IIIB and IV posing the greater level of risk to unprotected occular and skin tissue. Through the adoption of international regulations and evolving UK legislation related to healthcare, the use of higher-powered laser classes carries an obligation on the part of the dental professional to demonstrate an acceptable level of compliance and competence in their use in dentistry.

Current UK legislation and applied regulatory framework, in compliance with professional registration and scope of practice, allows the authority for clinical dental personnel to adjunctively use lasers in the delivery of dental treatment. Compliance with this framework is overseen by the CQC in England (and devolved authority in other UK regions); this mandates strict compliance with registration of laser use and associated appointment of a LPA and LSO to adopt local rules and procedure protocols within a dental practice setting.

Prime responsibility exists to address and contain known risk to the patient during the delivery of laser-assisted dental treatment. Additionally, all personnel authorised in the delivery of laser treatment must be aware of all potential risks and protocols mandated to ensure all safety measures are adopted and applied.

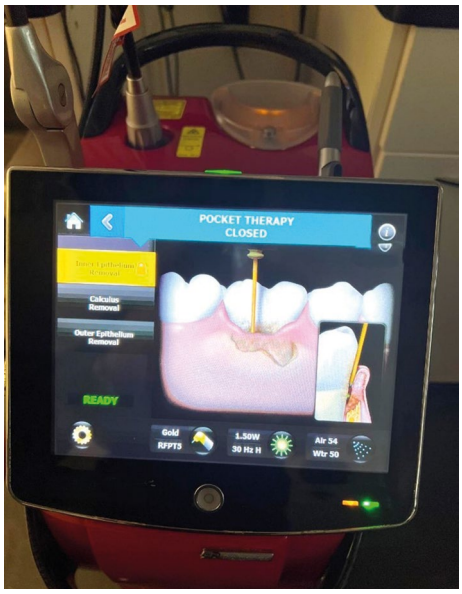

Fig. 11 Laser control panel

Fig. 12 Sample protective goggles, with reference to wavelength attenuation

Table 6 Objectives and procedure for laser test fire

Test fire objective	Test fire procedure
• Test operational ability/status of machine • Test cleave of fibre (as appropriate) • Demonstrate patency of delivery mechanism • Check power output (power meter) • Demonstrate patency of aiming beam/co-axial air/water.	• Define controlled area/personnel protocol/ protective eyewear • Use lowest power setting • Direct beam away from eyes • Use suitable absorption medium relative to the laser wavelength.

Ethics declaration

The authors declare no conflicts of interest.

Author contributions

Conceptualisation: SP; methodology: SP, MC; investigation and data extraction: SP; writing – original draft preparation: SP; writing – review and editing: SP, MC. All authors have read and agreed to the published version of the manuscript.

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When this Book Review was originally published online, there were errors in the book reference. This has been updated as follows, to correctly reflect the editors of this book:

S. R. Prabhu, Syed Ali Khurram, Omar Kujan & Merva Soluk Tekkesin

The journal apologises for any inconvenience caused.