AUSTRALIAN DENTAL ASSOCIATION

ADA Guidelines for the Use of Lasers in Dentistry

Document version: 2021-11

Clinical context

Laser have become more prevalent in dentistry in recent years as more players have entered the market and costs have decreased. High power solid state lasers are already available at modest cost. There are more laser systems available with dual or triple wavelength outputs, offering a wider range of treatments.

Lasers have the potential to generate time-saving and thus productivity increases. They can be useful for dentists whose practices have significant numbers of patients with aggressive forms of caries may find lasers improve their delivery of dental care and attract dental-phobic patients.

This practical guide offers background information and context to different laser systems, regulations, and the pros and cons of laser use which may assist dentists in evaluating the appropriateness of lasers for their practice.

Contents

Definition and principle of operation

The word LASER is an acronym for the process of Light Amplification by Stimulated Emission of Radiation, which is the means by which lasers generate visible, ultraviolet (UV) or infrared (IR) emissions.

The effect was predicted by Einstein in 1916 and demonstrated first by Maiman in 1960. Lasing occurs when laser-active atoms are raised from a ground state to excited states by absorption of electromagnetic energy. If the excited atoms are in a suitably designed cavity, they can be stimulated to emit dual photons. The emitted energy has a specific wavelength (is monochromatic), is coherent (the wave fronts are in step) and is collimated (the beams can be made to be parallel). These qualities allow laser energy to be focused on a very small area to produce an extremely high intensity, creating effects such as tissue ablation, water cavitation or bacterial inactivation. Laser light can also be used to activate normal body processes such as wound healing by interacting in non-thermal ways with enzymes inside cells.

Laser type and delivery systems

Lasers used in dentistry typically use materials in their solid state (such as crystals or semiconductors), or in gasses. The range of lasers available covers from ultraviolet to the far infra-red regions of the spectrum, and emit at powers from 25 milliwatts up to 25 watts or more. The laser energy may be delivered in a range of modes, including continuous wave, chopped, superpulsed or pulsed.

A description of the laser is found on its product information label. This label states details of both the primary of treatment beam(s) as well as the aiming beam (if present). The description states the laser by name, the emission wavelength, the maximum power or pulse energy of the treatment beam and aiming beam, and the hazard class of the laser (with Class 4 referring to the most hazardous type). It is also useful to know the duration and repetition rate of pulses, as this varies between manufacturers of the same laser type.

Some systems have multiple treatment wavelengths, and these may be delivered down the one optical fibre or through separate pathways.

To use a laser effectively it must be possible to deliver its energy conveniently and efficiently to the target material. For wavelengths from visible light (400-700 nm) up to the near infra-red region (2200 nm), a flexible glass optical fibre can deliver the energy. For middle infrared lasers (2780-2940 nm) used to remove enamel, dentine, bone, dental caries and calculus, flexible fibres made of rare earth element compounds can be used, as well as hollow wave guides or an articulated arm.

For far infra-red laser wavelengths (10,600 nm), hollow wave guides or articulated arms are used since there are no suitable optical fibre materials.

Interaction with oral tissues

Laser energy interacts with oral tissues and dental materials photochemically, photothermally, photomechanically, photoelectrically, or a combination of these. The type of interaction depends primarily on the target tissue optical properties (laser absorption characteristics) the laser wavelength, the power and energy density delivered, and the shape of the laser pulse.

Most lasers deliver a treatment beam and an accompanying visible red or green aiming beam, however there are now laser systems which can deliver two treatment beams simultaneously or in an alternating fashion where pulses of one follow the other.

For lasers used for oral surgery, the interaction with oral structures is primarily photothermal. The energy is absorbed at the surface of the soft tissue, which is vaporised or ablated. Below this, the penetrating laser energy causes coagulation and haemostasis.

Wavelengths in the middle and far infrared regions are primarily absorbed in water, as well as in apatite minerals, while those in the visible and near infrared range absorb primarily in haemoglobin and pigments rather than in water.

When pulsed lasers absorb in water, cavitation occurs as steam bubbles explode and implode, and the resulting shockwaves, fluid agitation and fluid streaming can assist debridement of hard tissues and implants. Shock waves from exploding water also play a part in the removal of tooth structure, bone and calculus.

Several laser effects are inherently not thermal in nature. Lower power lasers operating in the visible red and near infrared regions can cause non-thermal activation of cells by electronically exciting molecules. Laser photobiomodulation causes enhanced healing responses, or at higher exposures can cause analgesic actions by suppressing neuronal firing for a period of time. Low power lasers can also electronically activate photosensitiser dyes to cause release of oxygen radicals or other chemical effects. Finally, milliwatt-power lasers can be used to transilluminate teeth or elicit fluorescence for enhanced clinical diagnosis.

Lasers for dental use

Argon lasers (wavelengths 488 and 514 nm)

These lasers provide separate or combined blue and green wavelengths at adjustable energy levels, delivered by an optical fibre. The blue wavelength rapidly cures resin composite and other light cured materials. Both the blue and the green wavelengths are absorbed strongly by haemoglobin, and the beam cuts or coagulates vascular soft tissue very effectively.

The green wavelength approximates the absorption spectrum maxima of some tooth stains (for example, tetracycline) allowing this to be used for rapid photodynamic tooth bleaching.

Many of the surgical applications of the blue 488 nm argon wavelength have now been overtaken by visible blue diode lasers operating from 445-455 nm. The diode units are much more electrically efficient and are small, portable and can be powered by rechargeable batteries.

The green argon wavelength applications have likewise been overtaken by the KTP 532 nm laser (frequency doubled Nd:YAG). This is absorbed strongly by haemoglobin and the beam cuts or coagulates vascular soft tissue very effectively.

Diode lasers (range 395–980 nm)

'Low level or non-surgical diode lasers' (630–670, 800-830, and 900-940 nm). These deliver red (visible) or near infrared wavelengths at energy levels up to 500 mW. These lasers can promote healing and reduce pain and swelling through biostimulation or photobiomodulation. Lower exposure parameters (2-4 Joules per cm2) are used for biostimulation, and higher exposure parameters (10-12 Joules per cm2) for analgesia and desensitisation procedures.

Low power diode lasers in the <20 mW range are also used for fluorescence diagnosis (395-405 nm and 650-655 nm) as well as for transillumination and dental imaging (890-970 nm).

Many different low power diode lasers can be used to photo-activate chemical dyes for surface disinfection, with the dye being matched to the laser output.

'Surgical diode lasers" (445-455, 800-830, 940, and 970-980 nm)

These diode lasers can provide gated, superpulsed or continuous wave modes, and all can be delivered through fibre optics. Typical powers for minor oral surgery are 1-2 watts, however high power surgical diode lasers can deliver up to 15 watts. Surgical diode lasers provide excellent haemostasis. They are convenient because of their small size, light weight and convenient delivery systems, which often use disposable tips. During use, the tip temperature can be several hundred degrees or more while the laser is firing. The tip temperature is controlled by the user through initiation or coating procedures, which can be varied according to the desired effect. Initiated tips have a higher temperature and will cut tissue faster than non-initiated tips.

In conjunction with a suitable photoabsorbing bleaching gel, diode lasers can be used for photothermal enhancement of bleaching. All near infrared surgical diode lasers can be used at low power settings for biostimulation.

Neodymium/Yttrium-Aluminium-Garnet (Nd:YAG) lasers (1064 nm)

These pulsed lasers produce invisible, near infra-red light, delivered by an optical fibre. This wavelength is best absorbed by melanin and other pigments, making the laser useful for photothermal disinfection as well as for oral soft tissue surgery. The laser energy penetrates well through teeth making it also useful for desensitisation and analgesia. These lasers have also been used for disinfection, and in the laboratory for welding metals using high energy pulses.

Holmium/Yttrium-Aluminium-Garnet (Ho:YAG) lasers (2140 nm)

Ho:YAG lasers generate pulses of middle infra-red light at a frequency which is strongly absorbed by water and can be delivered by a specially modified glass optical fibre. The strong absorption makes this laser very effective for oral surgery (especially temporomandibular joint operations), haemostasis and wound debridement. Cost and size are both similar to Nd:YAG lasers. This laser will also ablate tooth structure.

Erbium/Yttrium-Aluminium-Garnet (Er:YAG) lasers (2940 nm)

Er:YAG lasers produce pulses of middle infra-red light which are strongly absorbed by water. This laser is very effective for cutting soft tissue, bone and tooth structure. Using longer duration pulses can increase the degree of haemostasis when ablating soft tissues.

It has many hard tissue applications, including the cutting of carious or sound enamel and dentine to leave an etched and smear-free surface suitable for direct bonding. The laser is used with a film of coolant water sprayed on the tooth. Water in the tooth structure absorbs the laser energy, and the resulting microexplosion causes fragmentation of the hard tissue. The same process can be used to remove calculus and subgingival dental plaque from teeth and dental implants. Explosions in water are also the basis for enhanced debridement of the root canal and activation of endodontic irrigation fluids. Specific patterns of pulses can assist in agitating fluids in the root canal system.

Er:YAG laser pulses from 15-20 pulses per second can be used to induce analgesia in hard and soft tissues, allowing cutting of teeth, bone and soft tissues with little or no local anaesthesia.

Some manufacturers offer versions of Er:YAG which incorporate another laser (for example, Nd:YAG, diode laser or Carbon Dioxide laser) into the same system.

Erbium, Chromium: Yttrium, Scandium, Gallium, Garnet (Er,Cr:YSGG) lasers (2780 nm)

As Er,Cr:YSGG laser light is strongly absorbed by water to a similar extent as for the Er:YAG, the Er,Cr:YSGG has the same range of clinical applications as the Er:YAG laser. Both laser types may offer variable pulse duration, with shorter pulses for cutting hard tissue and longer pulses for soft tissue surgery. The long pulse enhances the haemostatic ability.

Carbon Dioxide lasers (10,600 nm)

This laser delivers far infra-red wavelength light via an articulating jointed arm delivery system (which is permanent) or a hollow flexible wave guide (which has a life of several months to one year, depending on usage).

This wavelength is strongly absorbed by water and thus rapidly ablates soft tissues. This laser is particularly useful for debulking overgrown or hyperplastic tissue, and for surgical procedures on oral mucosa which require large surface areas to be treated. It can operate in continuous, chopped mode or superpulsed mode, with the latter giving the fastest ablation and the least surface carbonisation. It has been the gold standard medical surgical laser for many years.

A range of attachments can provide programmed sweeping of the laser beam over the target area to provide controllable ablation of such lesions as leucoplakia and lichen planus.

Potassium Titanyl Phosphate lasers (KTP)

This laser has an emission wavelength of 532 nm in the visible green spectrum. It is a frequency doubled version of the Nd:YAG laser, and can operate in both continuous wave and chopped modes. KTP lasers are driven using banks of temperature controlled diode lasers, which is why they can produce continuous wave emissions, while conventional Nd:YAG lasers are typically limited to microsecond duration pulses.

KTP laser energy is highly absorbed by haemoglobin, as well as by melanin and red or violet-coloured compounds, including the complexes which form between tetracycline antibiotics and dental hard tissues. This makes the KTP laser very useful for photodynamic bleaching treatments of tetracycline stained teeth.

KTP laser energy transmits through water better than any other laser, meaning that cutting, disinfection or other laser procedures can be done through water.

The KTP laser is used for cutting, vaporising and coagulating tissues, and gives a blood free and dry operating field. Unlike near infrared diode and Nd:YAG lasers, the glass optical fibre tips used with the KTP laser do not require initiation in order to accelerate the laser ablation effects.

Potassium Titanyl Phosphate lasers

Ultrashort pulse duration lasers

Lasers in the infrared range operating at very short pulse durations (down to the femtosecond range) have been used to pattern the surface of dental implants. These lasers can also ablate natural tooth structure and dental restorations very precisely with no attendant heat, making them suited to procedures where very high precision is needed. With very short pulse durations, delivery of the beam may need special delivery systems, such as single mode fibers, to prevent degradation of the laser pulses.

Laser advantages and disadvantages

Advantages

In surgical applications, the lack of tissue contact and high temperature during laser/tissue interaction reduce wound infection and post-operative pain, while the intrinsic coagulation reduces or eliminates bleeding and reduces pain, tissue shrinkage and scarring during healing.

Lasers can cause deep curing of visible light cured resins, and can enhance the chemical action of endodontic irrigation fluids.

The effective and painless removal of caries and preparation of cavities, with no local anaesthesia or vibration, improves productivity and patient acceptance of treatment.

Using laser photobiomodulation to reduce or eliminate pain or muscle spasm, or to promote healing may lead to a better patient experience as well as improved clinical outcomes.

Operator and staff training are required to obtain maximum benefit from laser technology.

Disadvantages

The cost of lasers varies over a wide range, from as little as several thousand dollars for diode lasers through to many tens of thousands for large surgical solid state or gas lasers. The low cost diode lasers have no appreciable servicing requirements other than replacement of rechargeable batteries which may be needed after several years. The cost of consumable items such as disposable tips must be considered in the cost structure of using a laser in dental practice. Large lasers require annual servicing where air filters and coolant fluids must be checked and where necessary replaced. Currently available handpieces are designed to meet the requirements for sterilisation between patients, however particular attention must be paid to this task, as generally the internal optics are removed or special seals placed to protect internal mirrors and lenses. Typically the handpieces for large surgical laser systems will have detailed instructions for correct reprocessing which must be followed closely to prevent damaging the optical components of the handpieces. Most laser handpieces have components which can be changed by the user if damaged, such as internal mirrors or windows.

Operator and staff training are required to obtain maximum benefit from this technology. Appropriate measures for laser safety such as protective glasses and warning signs are essential, as well as window blinds to prevent exposure of other persons while the laser is in use (for lasers with wavelengths below 2500 nm). Protective filters can be incorporated into loupes, faceshields and operating microscopes without difficulty.

Hazards associated with lasers

Across the globe, lasers are classified according to the hazard associated with their emissions, as defined in AS/NZS IEC 60825.1:2014 Safety of Laser Products Part 1: Equipment classification and requirements, and AS/NZS IEC 60825.14:2011 Safety of Laser Products Part 14: A User's guide.

A range of devices used in clinical practice employ low power lasers in such a way that the risk of damage to the eyes or skin of staff or patients is minimal or zero. Class 1 lasers are fully enclosed and their design prevents accidental exposure. Examples include laser welders, benchtop model scanners and laser printers.

Class 2 lasers emit visible light, and are less than 1 milliwatt (mW) in power. Eye protection is provided by normal aversion responses such as the human blink reflex. Such lasers are only dangerous if viewed for prolonged periods of time or through magnifying optical instruments. Examples include positioning lasers (in OPG and CBVT systems), diagnostic lasers (KaVo DiagnoDENT, KaVo DiagnoCAM) and laser-based intra-oral scanners.

Visible Class 3R lasers have powers less than 5 mW, while Class 3B lasers have powers from 5 to 500 mW. Class 3B lasers produce visible or invisible light that is hazardous under direct viewing conditions; either they are powerful enough to cause eye damage in a time shorter than the human blink reflex (0.25 seconds) or the blink reflex is by-passed due to the invisibility of the beam. Laser products with a power output near the upper range of Class 3B may also cause skin burns. These lasers are used in dental practice for antimicrobial photodynamic therapy, photobiomodulation and the treatment of pain and muscular disorders. Operators of these lasers plus assistants and patients must be protected from unintended or accidental eye or skin exposure to direct or scattered radiation during laser use.

Class 4 lasers are high power devices, with a power above 500 mW. These have been used in dental treatment in Australia since the mid-1980s. They are capable of causing both eye and skin burns, their diffuse reflections may also be hazardous and the beam may constitute a fire hazard. These lasers are used in dental practice for soft tissue surgery, hard tissue surgery (cutting of bone), tooth preparation and bleaching, as well as other applications that use photomechanical effects (such as agitation of fluids in endodontics) or photothermal effects (such as disinfection or coagulation). Operators of Class 4 lasers, plus assistants and patients must be protected from unintended or accidental eye or skin exposure to direct or scattered radiation during laser use. All Class 4 laser operators and team members working within the designated operating zone must have undergone training in laser safety, and where necessary, meet the training and licensing requirements of the local legislation (discussed below).

Laser regulatory requirements

Currently, three states (Queensland, Tasmania and Western Australia) have state based radiation safety legislation that prescribes the requirements for laser safety for Class 3B and Class 4 lasers used in health care settings, including dental practice.

Queensland

- **Legislation**: Radiation Safety Act 1999 (current vsn 1 October 2021) and the Radiation Safety Regulation 2021
- **Regulator**: Radiation Health https://www.health.qld.gov.au/radiationhealth
- **Devices**: Class 3B and Class 4 lasers.
- **Key aspects**: Registration of device with annual checking of performance, approval of premises (e.g. dental operatory), Radiation Safety Protection Plan, licensing of users, appointment of a Radiation Safety Officer (RSO). Users and RSOs must have completed an approved course in laser safety.

Tasmania

- **Legislation**: Radiation Protection Act 2005 (current vsn 20 June 2013) and Radiation Protection Regulations 2016
- **Regulator**: Department of Health and Human Services https://www.dhhs.tas.gov.au/publichealth/radiation
- **Devices**: Class 3B and Class 4 lasers.
- **Key aspects**: Registration of device with certificate of compliance, Radiation Management Plan, licensing of users, appointment of an RSO. Users and RSOs must have completed an approved course in laser safety.

Western Australia

- **Legislation**: Radiation Safety Act 1975 (current vsn 1 Dec 2018) and the Radiation Safety (General) Regulations 1983
- **Regulator**: The Radiological Council of WA http://www.radiologicalcouncil.wa.gov.au/
- **Devices**: Class 4 lasers, single pulsed Class 3B lasers and Class 3B lasers with average output power greater than 5 mW
- **Key aspects**: Registration of device, licensing of users, appointment of an RSO who has completed an approved course in laser safety.

In other jurisdictions in Australia (i.e. NSW, Victoria, NT, ACT and South Australia), the Nationally Harmonised Work Health and Safety Legislation applies. This common legislation stipulates duties of care for both employers and workers. The AS/NZS 4173:2018 Safe use of lasers and intense light sources in health care standard is designed to help employers and workers meet their obligations for safety in a workplace where lasers are being used. The Standard specifies requirements for the safe use of lasers and laser systems, and explains the procedural and administrative controls necessary for the safety of patients, health care staff, maintenance personnel and others who may be in the vicinity of the treatment room and in need of protection against inadvertent exposure. The informative part of the Standard describes the principles of laser operation and the nature of the associated hazards. Examples of specific guidelines for the safe use of lasers in dentistry and in other clinical applications are given in Appendix B of the Standard.

Recommendations

Dentists whose major activity is cosmetic dentistry should investigate the time-saving and thus productivity increase accompanying laser purchase. Dentists whose practices have significant numbers of patients with aggressive forms of caries should consider trialling a laser to decide whether it would improve their delivery of dental care and attract dental-phobic patients.

As more manufacturers have entered the field, the cost of lasers has decreased. High power solid state lasers are already available at modest cost. There are more laser systems available with dual or triple wavelength outputs, offering a wider range of treatments.

Any dentist thinking about acquiring a high powered laser for patient treatment should first consult with colleagues who use one, and also undertake a course on clinical laser applications and complete an approved course on laser safety before signing a purchase or lease agreement.

Related resources

ADA Policy Statement 6.29 – Laser Safety in Dentistry

ADA CPD, Dental Files "Low Level Lasers" and "Dental Technology" by Emeritus Professor Laurie Walsh AO

Contribute to the development of ADA guidance to the profession

This Guideline has been developed by ADA expert committees. Feedback from the profession is welcome and may be submitted to contact@ada.org.au for consideration in future guideline development.