Lasers in Paediatric Dentistry

The word LASER is an acronym for 'Light Amplification by Stimulated Emission of Radiation' produced by photon emission due to electron movement between an excited state to one of stability.

The light produced by a laser is monochromatic and has low divergence. The monochromaticity of laser light refers to the emission of pure 'colour' or single wavelength light determined by the laser medium used. The light emitted can be in the visible or non-visible spectrum, travelling in one direction only in a near parallel beam.

Lasers produce a range of biological responses in tissue, determined by energy conversions in bio molecules of the target tissue. The mechanism of energy conversion can involve heat, thermo-acoustic and photo-chemical processes. The degree of tissue response is related to physical parameters, importantly wavelength, absorption potential and power density. Knowledge of the distinct absorption characteristics of the target tissue and given wavelength allows precise selection of the correct laser for a given operative procedure.

The clear advantage of laser therapy is the ability to treat tissues in a precise and controlled manner with the absence of mechanical injury and significant reduction in thermal injury to the target tissue. The advantage to the patient is a decreased inflammatory response producing a decreased pain response and faster tissue healing. One of the earliest affects noted with pulsed laser therapy was the desensitisation of hard and soft dental tissues termed laser induced analgesia. Analgesia is induced at sub ablative settings causing selective depolarisation of A delta fibres and to a lesser extent C fibres. At therapeutic energy levels, patients notice a reduction in rapid, sharp, localised pain however may notice photomechanical shockwaves and temperature change due to water evaporation, but not discomfort.

Laser assisted surgical procedures should not be dictated by the surgical instrument, rather normal surgical practice should be followed and where applicable, laser therapies can be of assistance. Correct surgical training, knowledge of laser physics and tissue interactions are necessary to provide safe and effective treatment. It is important to recognised lasers in dentistry are one of all tools available in the surgical armamentarium.

LASER TYPES AND APPLICATION

The range of applications for lasers in dentistry including paediatric dentistry is extensive, supported by a number of textbooks and peer review publications. The four basic applications in common use are laser fluorescence, soft tissue and hard tissue therapies and photo activated disinfection.

Laser fluorescence is a non-invasive diagnostic tool assisting in the detection of dental caries. The underlying principal relies of the fluorescent properties of enamel and dentine that are altered by mineral loss. The most commonly available laser fluorescence device utilises an In:Ga:As:P medium emitting light at 655nm in the visible red spectrum. Caries is detected by measurement of the mean percentage change in fluorescence between sound and demineralised tissue. This parameter has been found to correlate with the degree of mineral loss and histological depth of the lesion.

The advantage of laser fluorescence as a diagnostic tool is minimal invasion and high sensitivity. This allows for frequent investigation detecting and reviewing early disease progression, facilitating interceptive therapies before the need for irreversible restorative management.

Care must be used in the interpretation of laser fluorescence readings. Intrinsic and extrinsic staining along with enamel dysmineralisation can elicit false readings. Laser fluorescence should be used in conjunction with other diagnostic tools in determining the patient's caries risk.

Lasers emitting in the 808 to 980nm wavelength are applicable for soft tissue therapies as the wavelengths are strongly absorbed by chromophores including haemoglobin and melanin. The mechanism of the diode laser involves the conversion of laser energy into heat, achieving very high temperatures due to a high power density. The wavelength determines the depth of penetration and degree of haemostasis.

Tissue heating with a diode laser produce four therapeutic effects. Temperatures below 43 degrees Celsius have no irreversible effect but may have a bio-modulation potential. Temperatures between 43 to 60 degrees Celsius produce protein denaturation and coagulation through to cell mortality with sustained exposure. This affect is utilised in decontamination of tissues and tissue spaces, especially periodontal application. Temperatures up to 100 degrees Celsius produce a phase change of water and cell rupture, again useful in decontamination and debridement of diseased tissues. Temperatures above 100 degrees produce carbonisation and ablation with effective haemostasis, allowing surgical excision and tissue ablation dependent on beam focus. Thermal damage is limited and confined to cell layers immediately adjacent to the contact tissue, minimising the local inflammatory response. Excessive exposure time produces increased tissue damage.

Surgical application of diode lasers should follow normal surgical protocols and not be compromised by the ease of use of the laser as a surgical instrument. Common applications include analgesia, haemostasis, periodontal surgery, periodontal decontamination therapies and other soft tissue surgical procedures where bone is not involved. Correct surgical protocols for each treatment type remain indicative.

Bio-modulation is a collective term used to describe bio-stimulation and bio-inhibition produced by low level laser therapy (LLLT), at wavelengths in the visible red (633 – 635nm) and near infrared (810-830nm) spectrums. Bio-stimulation is initiated by a cascade of metabolic events induced by the absorption of laser light by photoreceptors in cell membranes and mitochondria. The effect on the electron transport chain activates Na+/K+ ATPase activity causing a broad activation of normal cellular functions. Energy densities of 1 -4 J/cm^2 produce tissue effects including increased microcirculation, stimulation of lymphatics, increased macrophage and fibroblast activity and changes in action potential of nerve tissue. Therapeutic usage in dentistry allows accelerated healing of soft tissues, maximised by repeated dosages. Ongoing investigations are illustrating similar healing potential in bone.

Bio-inhibition occurs with power densities above 8 J/cm^2 causing a reduction in cellular activity and tissue healing. LLLT therapies are an area of ongoing research and careful understanding of tissue interaction allows useful employment of LLLT in paediatric dentistry.

'All tissue' lasers used in dentistry produce extremely high power densities at wavelengths highly absorbed by water (Nd:YAG 1060nm, ErCr:YSSG 2780nm, Er:YAG 2940nm) and hydroxyapatite (CO_2 10600nm). Extremely short-pulsed delivery produces a photo-acoustic effect of very high temperatures lasting only the time of the pulse resulting in a disruptive expansion shockwave. Through this thermally induced explosive process, whole tissue fragments are ejected and a hole is produced with little to no alteration to adjacent tissue. Wavelengths of 2280nm and 2940nm are highly absorbed by water and OH^- due to a broad peak absorbance band around 3000nm. There is reduced absorbance at around 2800nm by the PO_4^{3-} molecules in hydroxyl groups in the hydroxyapatite of dental and bone tissue. The CO_2 laser is highly absorbed by hydroxyapatite, as the primary absorber is the PO_4^{3-} molecule at 9000 – 10000nm. The absorbance by water is less at this wavelength however the high temperatures produced by the CO_2laser produces effective haemostasis with soft tissue applications.

The photo-acoustic effect on target chromophores results in immediate evaporation causing highly localised rupture of the tissues. The typical macroscopic result at therapeutic dose in enamel is a disruptive expansion of 30 to 50 microns deep per pulse, the diameter dependent on the focusing tip. The depth of penetration in hard and soft tissue is dependent on power density used depending on the therapy indicated. Minimal heat is generated where the absorbance is modulated by water. Due to the net heat release due to water evaporation, thermal injury is limited. Higher power densities cause carbonisation. As with all hard tissue surgical techniques, it is essential to maintain co-axial water cooling to prevent overheating and collateral thermal injury. A degree of haemostasis is achieved within soft tissues and bone, however not to the degree of diode lasers. This is an advantage in bone surgery allowing continued blood perfusion of treated tissue.

Laser induced photochemical modalities in dentistry are primarily photo-activated disinfection. The principal uses a photosensitiser that when exposed to light at its peak absorption (commonly ~ 630nm), reacts with molecular oxygen to produce the higher energy singlet oxygen. This causes oxidative injury to membranes. Injury to non target cells is avoided by the differential effectiveness of the photosensitiser against rapidly dividing cells, including bacteria. The technique is reported to also be effective against viruses and fungi. Photo-activated disinfection may have clinical application in paediatric endodontics, decontamination of cavity preparations and periodontal disease, however limited literature is available to assist clinical decisions. Noting the current interest in the safety of some paediatric endodontic medicaments, further investigation would be encouraged.

TRAINING

All clinical staff should have a working knowledge of laser tissue interactions and applications. All clinical staff should be trained in correct operating procedures including set-up, handling, intra-operative monitoring, sterilisation and maintenance of the equipment. All users of Class 4 lasers may be required to hold proof of appropriate education and training in compliance with national, state or local legislation. Licensing of the operator, laser equipment and surgery may be necessary and varies between states. The use of Class 2 lasers is less restrictive.

HAZARDS

As with any surgical instrument, lasers can expose the operator, patient and clinical staff to a variety of hazards. The majority of lasers used in operative dentistry are Class 4 lasers. The principal risk is accidental irradiation by laser light, directly or indirectly by reflection. The greatest risk is to the eyes and skin. The risk of contact and inhaled exposure to contaminants directly and within the laser plume is also recognised. The correct use of protective protocols including wavelength specific eyewear where applicable is mandatory. Other potential risks are related to failure of the laser device.

Class 2 lasers (laser fluorescence devices) emit visible radiation where eye protection is normally afforded by aversion responses including the blink reflex.

SUMMARY

1. Laser assisted surgical applications are recognised as alternatives to traditional surgical techniques for hard and soft tissue therapies. The ability to treat tissues in a precise and controlled manner with significant reduction in collateral tissue injury, rapid healing and analgesic properties make the procedures favourable to paediatric dentistry.
2. Where laser assisted therapies are to be employed, correct surgical technique guided by established protocols must be maintained. Inadequate technique or understanding of the surgical procedure will lead to less effective therapy and possible increased morbidity.
3. Clinicians introducing lasers therapies into clinical practice need to ensure all staff have a working knowledge of laser tissue interactions and applications. All clinical staff should be trained in correct operating procedures including set-up, handling, intra-operative monitoring, sterilisation and maintenance of the equipment.
4. All users of Class 4 lasers may be required to hold proof of appropriate education and training in compliance with national, state or local legislation. Licensing of the operator, laser equipment and surgery may vary between states.

Nomenclature

In:Ga:As:P:	Indium:Gallium:Arsenic:Phosphorous
Nd:YAG:	Neodymium:Yttrium,Aluminium,Garnet
ErCr:YSGG:	Erbium,Chromium: Yttrium,Scandium,Galium,Garnet
Er:YAG:	Erbium:Yttrium,Aluminium,Garnet
CO_2 :	Carbon Dioxide

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Tim Johnston, Paediatric Dentist, Perth. BDSc MDSc FRACDS FADI