Lasers in dentistry

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The discovery of lasers in the early sixties has opened up a new era in the field of medicine and surgery. Research has been directed to introduce laser technology in the field of dentistry. Advancement has occurred in diagnosis, treatment planning, procedures in soft and hard tissues and orthodontics. In the early evolutionary state, better understanding of the tissue reaction and refining of the technique will improve the scope of lasers in clinical dentistry.

Laser is the acronym of the words 'Light Amplification by Stimulated Emission of Radiation'. Most lasers are heat-producing devices converting electromagnetic energy into thermal energy. More recently new types of lasers have offered non-thermal mode of tissue interaction.

Historical review

In 1917 Albert Einstein explained the mathematical relationship of three atomic transition processes, viz. 1. Stimulated absorption, 2. Spontaneous emission, 3. Stimulated emission.

Einstein postulated that light energy can induce energy transition in atoms causing the atoms to move from their ground state (EO) to the excited stage/activated stage. This is due to the absorption of a quantum of energy by the atom. This is called 'stimulated absorption'.

Because the lowest energy state is the most stable, the excited atom tends to return to normal by spontaneously emitting a quantum of energy called spontaneous emission.

This conversion to low energy state can also be achieved by stimulating the activated medium further by a quantum of light at the same transition frequency. This is called 'stimulated emission'. During this process it releases a photon of the same size as of the released atom, which hits against the adjacent activated atom setting off a chain reaction of releasing photons. This is the principle on which all lasers work.

The first laser was constructed by Maliman[1] using a bar of synthetic ruby made of alumina oxide doped with chromium oxide. Javan[2] discovered the first gas laser using helium–neon as the active medium. Patel *et al.*[3] in 1964 developed carbon dioxide laser. Today there are more than 600 laser media which can emit laser radiation of different wavelengths.

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Principle

The common principle on which all lasers work is the generation of monochromatic coherent and collimated radiation by a suitable laser medium in an optical resonator. The basic components of a laser equipment are:

Active medium

It is an atomic environment that supports stimulated emission. The lasers are named after the active medium. The medium can be gas (e.g. argon, krypton, carbon dioxide, helium with neon). It could be a liquid (dyes), or a solid, (e.g. neodymium–yttrium–aluminium–garnet (Nd–YAG), *eberium–yttrium–aluminium–garnet* (Eb–YAG) or a semiconductor. Rare gas atoms can react with halogens to form diatomic halides, called excimers. Decay of these excimers produces emission of protons with ultraviolet freqµency e.g. Ar–F (193 nm) Kr–F (249 nm) Xe–F (351 nm).

Incident energy source

It is used to stimulate the medium, the process called pumping. Gas lasers are pumped by electrical discharge between electrodes. Dye lasers are pumped by other lasers and solid lasers are pumped by incoherent light. If the medium is pumped first and then stimulated it produces pulsed laser beam.

Optical resonator

This promotes stimulated emission and supresses spontaneous emission. Concave mirrors are placed at each end of the beam path to cause reflected light to pass back and forth through the active medium producing a very bright, unidirectional, monochromatic laser beam.

Properties

Monochromaticity. The laser equipment amplifies the rays of the same frequency. The resulting pure or monochromatic beam produced is only 0.01 nm (10^{-9} m) in diameter.

Coherence. It is the degree to which the electromagnetic field of the light wave varies. The laser beam spreads very slowly. This property allows the beam to collect and focus at a particular spot.

Polarization. It is another aspect of coherence. Polarization is incorporated in the laser system to allow maximum transmission without loss caused by reflection.

Intensity. The intensity and duration of laser can be controlled by altering the input.

The main characteristic of laser is the wavelength which depends on the laser medium and the excitation mode, i.e. continuous wave or pulsed mode.

Laser–tissue interaction

The interaction of laser radiation with tissues is complex in nature and not completely understood. The effect of laser depends on:

1. Properties of the lased material (e.g. specific absorption chemical structure, density, etc.)
2. Properties of the laser (e.g. wavelength, energy density and pulse duration).

The effect of laser on the tissues can be grouped into:

Photochemical effect

This type of reaction occurs with low energy-long duration laser irradiation. The effect is due to the absorption of laser light by the tissue without any thermal effect leading to a change in the chemical and physical properties of the atoms and molecules. e.g. photodynamic therapy with HpD (a derivative of hepatoporphyrin).

Thermal effects

These are due to absorption of laser light by the tissue which converts it into thermal energy producing an increase in the internal lattice vibration. The elevated thermal energy vapourizes the tissue.

Nonlinear effects

This tissue reaction occurs with lasers of high energy densities (more than 107 wcm^{-2}) and short pulse duration (less than 1 ms). The heat conduction is minimal and non-thermal effects predominate in the tissues. Nonlinear reactions are of two types:

Photodisruption. The tissue destruction occurs mechanically independent of absorption of laser energy. The high energy laser ionizes tissue by building up plasma which dissipates explosively at high temperature.

Photo ablation. In this process the high energy laser light directly dissociates the tissue molecules. Only excimer laser emits radiation enough for electron dissociation.

Biostimulation

Low-powered laser irradiation stimulates healing and regeneration of tissues. These lasers are classified as soft lasers.

Tissue interaction	*Lasers*
Photothermal	CO_2, Nd–YAG, Er–YAG
Photodisruption	Nd–YAG, dye
Photoablation	Excimer, Er–YAG, CO_2
Photodynamic	Dye, metal vapour
Biostimulation	He–Ne–diode

Types of lasers

Lasers are of two types:

Soft lasers

They are low power lasers which emit in the visible or near infra-red region of the spectrum. They are essentially an aid to wound healing and treatment of pain.

The main soft lasers are:

i) Helium–neon laser
ii) Gallium–arsenide laser
iii) Gallium–aluminium arsenide laser

Uses of soft lasers:

1. Tissue regeneration
2. To promote healing and relieve pain in apthae
3. Treatment of dry socket
4. Desensitize enamel.

Mechanism of action

Biostimulation. The use of low power radiation to stimulate tissue repair was first reported by Mester, Gynes and Tota[4]. Rosaman *et al.*[5] reported that laser irradiation of gingival tissue immediately following extraction resulted in faster healing with minimal oedema and discomfort. Lased intraoral wound showed a faster healing with less apparent scar formation.

Lyons and Abergel[6] speculated that the mechanism of enhanced wound healing is by the stimulation of fibroblasts and improved organization of functional collagen fibres.

Mester[7] suggested that the laser irradiation may increase the development of blood circulation within the regeneration tissue. It has also been suggested that in the treatment of persistent ulcer, the stimulation of wound healing by laser irradiation may be due to immunosuppressive effect.

Boulton and Marshall[8] reported that cultured human fibroblasts irradiated with pulsed He–Ne laser increase cell division compared to nonirradiated cells. The DNA synthesis is also found to be stimulated by low intensity laser irradiation.

Lasing the apthous ulcer is found to produce immediate pain relief and faster healing.

Pain. The use of soft lasers in the relief of pain is mainly by laser irradiation of peripheral nerves and laser stimulation in acupuncture.

Zho[9] reported that laser acupuncture anaesthesia for dental extractions has been used in China since 1979. For surgical extractions and minor operations in the maxillofacial region, one or two appropriate acupuncture points are irradiated for 1–5 min with a He–Ne laser. Strang and Moseley[10] recorded good anaesthetic effect in 95% of cases treated with laser.

Walker[11] found good results with laser irradiation for the treatment of neurologic and musculoskeletal disorders. Soft lasers can also be used for desensitizing exposed dentin.

Hard lasers

The hard lasers are used for surgical procedures on hard tissues like bone and teeth. The commonly used hard lasers are carbon dioxide lasers, Nd–YAG and excimer lasers. The carbon dioxide lasers have long wavelengths which can only be transmitted through mirror systems. The new types of lasers have low wavelength which can be transmitted through fibre optic cable delivery system. This enables flexibility for intraoral use. The new q-switched Nd-YAG laser has extremely short pulse with high pulse energy.

Er YAG lasers have the added advantage that they can be used both on the soft and hard tissues with minimal thermal side effects.

Uses of hard lasers

Lasers have wide application in all fields of dentistry from basic research to clinical application.

Measurement and diagnosis. Laser holographic technique can be used in the experimental studies of tissue displacement. Laser diffraction is used to study the material adaptation and laser diffusometry to assess surface smoothness. In restorative dentistry the optical contour mapping of occlusal surface can be used to determine wear of enamel with micron range accuracy.

Lasers transillumination shows up enamel defects and incipient caries. In endodontics it gives a three-dimensional image of root canals which is not possible with X-rays. Based on ultraviolet-induced flourescence spectroscopy, a new technique has been developed to detect residual tissues at different levels of the root canal. Lasers can also be used to measure the length of the root canal.

Prevention of dental caries. The effect of laser on dental tissues was first investigated by Stern and Sognnaes[12]. They demonstrated that infra-red laser irradiation increases the acid resistance of tooth enamel. The effect is due to the conversion of hydroxyapatite crystals into more insoluble orthophosphate apatite crystals during the recrystallization of lased enamel. Studies by Yamamoto and Ooya[13] have shown that subsurface carious lesion can be prevented in laser-treated enamel surface. An increased acid resistance is obtainable by a combination of fluoride application and laser irradiation.

The argon and helium–cadmium lasers are effective in detecting incipient caries. The healthy enamel shows a characteristic luminescence compared to the caries-affected enamel.

Restorative dentistry. The use of lasers in restorative dentistry is extensive from cavity preparation to photocuring of composite resins. Nd-YAG and carbon dioxide lasers can be used for selective removal of decayed tooth material, but has no effect on normal enamel. This provides better retentive areas in enamel and dentin. During cavity preparation for undermining caries or preparation for final restoration, an air-rotor is used in conjunction with laser.

For fissure sealant procedures, lasers can remove organic and inorganic debris from the pit and fissure without injuring sound enamel. The pits and fissures can be sealed off by welding synthetic hydroxyapatite compounds. Lasers can also be used to condition the enamel surface before composite restorations.

Argon-ion lasers emitting light in the ultraviolet and deep blue range (450–500 nm) can replace a halogen source in the curing of composites. Homogeneous penetration of laser beam reduces shrinkage of the composite resin. The higher conversion percentage of monomer is indicated by the higher vickers harness compared with the halogen source.

Lasing restorative and crown and bridge preparations just before insertion or cementation recorded a reduction in post-treatment sensitivity. New techniques using lasers have been developed for bleaching vital and non-vital teeth.

Ar-F laser (193 nm) provides a guideline for the preparation of dental tissues. The laser beam induces a specific fluorescent light depending on the structure of the teeth. Comparing the fluorescent spectra with standard spectra enables cavity preparation within a range of a few microns.

The disadvantage with carbon dioxide and Nd–YAG Lasers is that the heat generated can cause cracks and charring of the dentin and enamel surface. The pulsed Eb–YAG and excimer lasers can overcome this disadvantage as the heat generated is low and the thermal side effects are minimal. At present the Ar–F excimer laser with 193 nm wavelength meets the ideal requisites for dental procedures.

Endodontics. Laser makes one sitting root canal treatment possible. The pulp tissue is vapourized, leaving the canal sterile. Apicectomy can be performed and the apex sealed off using carbon dioxide and Nd–YAG lasers.

Nd–YAG and carbon dioxide lasers make the root cânal dentin smooth and non-porous. This decreases dentinal permeability and reduces leakage following root canal obturation. The root canal filling material can be fused with the dental walls. The treatment of fractured root posed difficulties necessitating extraction. This is overcome by laser which has the potential to fuse fractured segments. The latest development in endodontics is laser pulpotomy.

Prosthetics. Lasers can be used for repairing alloy bridges intraorally. The inaccuracies resulting during transfer from the master cast are avoided. Laser is used in the design of prosthetic appliances. The commercially available CAD/CAM system uses a solid state laser to optically scan a preparation and develop denture pattern. Goran and Smith[14] found the weld joint to be harder, stronger and better corrosion resistant.

Implantology. Lasers can be used to weld titanium implants to the metallic part of prosthetic suprastructure. In producing the jaw-bone-anchorage bridge, each section is fabricated separately and the sections are joined by laser welding.

For crown and bridge work, laser can replace the retraction chord providing hemostasis. This improves visualization of prepared margin, reducing the chance for defects and provides better adaptation. The penetration depth of argon lasers is advantageous in prosthetic veneer and adhesive bridge work.

Orthodontics. The lasers can be used for etching the enamel. Since Nd–YAG wavelength is not absorbed by enamel, a dye is placed on the site to be etched. Clinically there is 50% saving in time in laser etching compared with phosphoric acid. Laser etching avoids the need to protect the gingival tissue as with acid etching. The composite for direct bonding can be cured using lasers. The bond strength of the laser-cured composite is found to be superior to light-cured composite. The main advantage of bonding with laser is the reduction of decalcification around the brackets. The ability of lasers to weld titanium wires enables to attach auxillaries which was not possible with conventional welding techniques.

The use of lasers for debonding ceramic brackets reduces the incidence of enamel fracture. Lasing also reduces the shearing force needed for the removal of brackets.

Periodontal surgery. Lasers can be used for gingivectomies, gingivoplasties and excision of fibromas with minimal bleeding.

The periodontal pockets can be treated by a noninvasive procedure called laser curettage. The laser optical fibre (320 microns) is inserted to the depth of the pocket and lased in a criss-cross manner. The fibre follows the root contour in a parallel fashion towards the diseased epithelium causing vapourization. The advantage is that the procedure can be done without anaesthesia and post-treatment complaints are minimal. Pockets become asymptomatic within 48 hours.

Laser gingivectomy for removal of dilantin hypertrophy is being studied extensively. The gingival healing and pain is less. This may be due to the protein coagulum that is found in the wound surface which acts as a biologic dressing.

Lasers can remove calculus from periodontally affected root surface by ablative photodisruption with minimal adjacent tissue trauma. This enhances periodontal regeneration. The lased root surfaces remain smooth which is not possible with hand instruments.

Paediatric dentistry. Paediatric dentists reported a high rate of success in laser analgesia for young patients undergoing dental procedures. The tooth to be desensitized is lased for 2–4 min. The anaesthetic effect is temporary lasting from 10 min to 1 hour. The success rate when used in adults was found to be less. Due to the minimal discomfort during dental procedures the children are found to cooperate better with laser procedures than conventional methods.

Desensitization. The sensitivity resulting from exposed dental tubules can be treated by lasing the affected area. Sensitivity is reduced usually in one treatment. A second lasing is sometimes needed after two weeks. White and Goodis[15] found lasing changed the hydraulic conductance of the fluid in the dentinal tubules and stimulated secondary dentin formation. Cases are found to remain asymptomatic up to two years. Newly exposed dentin and cementum if lased immediately after periodontal surgery show dramatic reduction in the post-treatment sensitivity.

Surgical procedures. The unique properties of lasers make it ideal for many surgical procedures. They are used to remove fibromas, drain abscesses and perform various biopsies. Lasers minimize cellular destruction compared with knives and electrosurgery. It coagulates blood vessels less than 0.5 mm in diameter, enabling a blood-free operating site. This also reduces the blood born contamination. The substitution of clotting factors in haemorrhagic disorders is not required in minor surgeries as Nd–YAG lasers are available for coagulation. Another advantage is the sterilization of the wound while cutting due to the laser's thermal antiseptic effect. This minimizes the postoperative infection.

The use of lasers in surgical procedures results in minimal inflammatory reaction, faster healing with little scarring and contraction. Lasing cut wound surface is found to reduce postsurgical pain.

Myers[16] has documented the local anaesthetic effect of lasers. Many of the minor clinical procedures can be performed without local anaesthesia.

During the reconstruction of facial defects, laser doppler flowmetry can be used to measure the flow of blood in the flaps or transplants. This gives an assessment of the vitality of the flap.

Disadvantages of lasers in surgery

If laser is used in skin, subcutaneous, facial and muscle tissues, there is potential delay in healing due to coagulation of lymphatic and small vessels. One of the initial transient disadvantages is the loss of tactile feed back in using the instrument. Since most surgical instruments provide tactile feedback, it takes time to get accustomed to using the no-touch technique of lasers.

Anticancer therapy. Photodynamic therapy (PDT) as described by Lofgren[17] is an alternative in the treatment of malignant tumours. A cancer seeking photosensitive drug is administered which accumulates in the tumour. The tumour is later irradiated with laser light, which makes the photosensitizer cytotoxic, thereby destroying the tumour. This is of great help in the treatment of advanced cancers where conventional therapy is difficult. There are two procedures using lasers in the removal of soft tissue pathologies: a) Excision; b) Vapourization. Vapourization has the disadvantage that small fragments of pathologic tissue may remain in the deeper layer, resulting in recurrence. Also no biopsy specimen is available for laboratory evaluation.

Sterilization. Sterilization of surgical and dental instruments can be done using lasers. Powell *et al.*[18] found that surgical instruments could be sterilized in 30 sec using a 3-watt argon laser.

Hazards of laser

Lasers are classified according to the classification system described by BS 4803 (British Radiation Safety Standards Institution). Soft lasers are class 3B laser products. This means direct viewing into laser beam is hazardous but viewing by diffuse reflection is not.

For hard lasers with wavelength 400–1400 nm, the principal danger is retinal injury. This may result in a reduction in the field of vision to total blindness. The wearing of protective eye wear is compulsory for patient, operator and the assistants. The wavelength of the laser determines the type of protective eye wear. Wearing wrong goggles is more dangerous than not wearing them at all.

Other complications are the necrosis of pulp and soft tissue and skin damage due to over-exposure. Transillumination with helium neon/green argon laser produces a scintillating effect within the tooth which is visibly tiring and disturbs visual resolution. Some of the radiation is non-ionizing and can cause physiological and behavioural effects.

The future

Some of the latest technical advances offer new perspectives in caries treatment, periodontology, bone surgery by seeking to replace conventional drills and hand instruments with the laser system. The use of the non-thermal process of photoablation with excimer laser seems to be the future in dentistry. The frontier is open for many trends and possibilities. But there is a long developmental period ahead before the technique is thoroughly understood and mastered.

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REVIEW ARTICLES

How do senescing leaves lose photosynthetic activity?

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Delay in leaf senescence to a maximal extent is an agronomically desired trait. The photosynthetic capacity of senescing leaves is usually much lower than their normal counterparts. The onset of senescence involves major changes in various characteristics of ribulose-1,5-bisphosphate carboxylase/oxygenase, the enzyme which is thought to rate-limit photosynthesis. In addition, certain selective and specific changes take place in the electron transport process of the senescing chloroplasts. This article provides information on senescence-associated alterations in various partial reactions of photosynthesis and on gene expression which accompany this phenomenon.

LEAF senescence is a critical developmental shift in the life of a green plant. The research on leaf senescence has been carried out with wide range of interests. It is a challenging area for plant biologists who wish to understand the fundamental aspects of plant development. The physiologists and biochemists are interested to investigate the metabolic interactions which characterize senescing leaves. To an agronomist, senescence is important because it limits the supply of assimilates to the growing seeds. This phenomenon provides an opportunity to a molecular biologist to unravel mechanism(s) responsible for differential gene expression and poses challenges for devising novel strategies to delay it. The objective of this review is to assess various possible reasons which together result in reduction of photosynthetic capacity of the senescing leaves. It will cover information on interaction of leaf senescence and photosynthesis and give a detailed account of the influence of senescence on ribulose-1, 5-bisphosphate carboxylase/oxygenase (RuBP carboxylase) and on photosynthetic light reaction components. Finally, comments on gene expression changes during senescence will be documented. For more details concerning metabolic and regulatory events of leaf senescence,