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Lasers in Conservative Dentistry And Endodontics- A Review

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Abstract: *The dental lasers of today have benefited from field of quantum mechanics, initially formulated during the early 1900s by Danish physicist Bohr. The first laser use in endodontics was reported by Weichman & Johnson (1971) who attempted to seal the apical foramen in vitro by means of a high power-infrared (CO_2) laser. In May 1990, Myers and Myers developed the first specialized dental laser (pulsed Nd:YAG) called de-lase300.*
Keywords: *Laser, Co2, Nd-YAG, Pulp*

I. Introduction

A laser is a device that transforms light of various frequencies into a chromatic radiation in the visible, infrared, and ultraviolet regions with all the waves in phase capable of mobilizing immense heat and power when focused at close range The intraoral use of lasers, when used efficaciously and ethically is an exceptional modality of treatment for many clinical conditions that dentists or dental specialists treat on a daily basis.

Fundamentals Of Lasers

An electron whirls in an orbit surrounding a nucleus. This electron ordinarily is in a low energy state, with its domain in the ring most immediate to the nucleus.

If a photon - a unit of energy strikes the atom, the electron absorbs the energy and is transferred to a more excited state which is less stable than the resting or low – energy state [1]. The electron now occupies an orbital ring more distant from the nucleus. This process is called absorption.

Once an electron moves to a higher-energy orbit, it eventually wants to return to the ground state. When it does, it releases its energy as a photon - a particle of light.This phenomenon is termed spontaneous emission of radiation.

When an atom in the excited state becomes irradiated with a photon of light energy of the same wavelength and frequency that was previously absorbed, as it returns to its resting state, it will emit two photons of light energy of the same direction in spatial and temporal phase. This is the stimulated emission of radiation [Fig 1]

Properties Of Laser Light

- Monochromatic (single wavelength)
- Collimation(specific boundary)
- Coherency (in phase)
- Directional (narrow cone of divergence)

A Laser light has one specific color; a property called monochromatic; and is finely focused. Collimation refers to the beam having specific spatial boundaries. These boundaries ensure that there is a constant beam size and shape that is emitted from the laser unit.

Coherency is a property unique to lasers. The light waves produced by a laser are a specific form of electromagnetic energy. A laser produces light waves that are physically identical. They are all in phase with one another; that is, they have identical amplitude and identical frequency [Fig 2]

Lasers Used In Dentistry

- Argon
- Diode
- Neodynium:YAG (Nd:YAG)
- The Erbium Family
  Erbium Chromium: YSGG
  Erbium:YAG
- CO_2 LASER

- Plasma Arc Curing (PAC)

Uses of Lasers In Endodontics :
- ➢ Pulp diagnosis
- ➢ Pulp capping and pulpotomy
- ➢ Cleaning and shaping of the root canal system
- ➢ Endodontic surgery

Pulp Diagnosis
Laser Doppler Flowmetry:
LDF was developed to assess blood flow in micro vascular systems.
- The original technique utilized a light beam from a He-Ne laser emitting at 632.8 nm, which when scattered by moving red cells, underwent a frequency shift according to the Doppler principle [2].
- A fraction of the light back scattered that is Doppler shifted is detected and processed to produce a signal that was a function of the red cell flux.(volume of cells illuminated x mean cell velocity.)
- This information can be used as a measure of blood flow, the value being expressed as a percentage of full scale deflection. (% FSD)

  Advantages :
- It reflects vascular rather than nervous responsiveness
- Used in situations like teeth that had recent trauma or are located in part of the jaw that may be affected following orthognathic surgery , which can lose sensation while intact blood supply and pulp vitality are maintained.

  Limitations :
- Difficult to obtain laser reflection from certain teeth.(molar teeth with thicker enamel & dentin and variability in the position of the pulp within the tooth , may cause variations in pulpal blood flow
- Differences in sensor output and inadequate calibration by the manufacturer may dictate the use of multiple probes for accurate assessment.
- Values may vary i.e sometimes may not be reliable indicator due to problems such as artifacts.

a. indication of changes in red cell flux in gingival tissue
b. changes in ambient light intensity
c. movement artifacts.

Advantages over EPT:
- ▪ Can be used in traumatized teeth
- ▪ Does not rely on painful sensation to determine vitality

Pulp Capping And Pulpotomy:

Pulp capping:As defined by AAE – " A procedure in which a dental material is placed over an exposed or nearly exposed to encourage the formation of irritation dentin at the site of injury."
Pulpotomy: "It entails the surgical removal of a small portion of vital pulp as a means of preserving the remaining coronal and radicular pulp tissues."

Advantages of lasers
- ➢ Bloodless field
- ➢ Sterilization of the treated wound
- ➢ Hemostasis
- ➢ Improved restoration (scarring) of the dentin tissue through the formation of secondary dentin

Direct pulp capping:
- ▪ Moritz et al used Co_2 laser for direct pulp capping
- ▪ The energy level of 1 W at 0.1 second exposure time with 1 second pulse intervals was applied to the exposed pulp
- ▪ Teeth were check for vitality after 6 and 12 months and 89.4% of the teeth retained their vitality
- ▪ Melcer also described successful pulp restoration after direct capping of inflamed pulps with laser irradiation
- ▪ According to Paschoud and Holz, 1988 laser treatment causes direct stimulation of dentin formation
- ▪ Jukic et al used Co_2 and Nd:YAG lasers on exposed pulp tissue and reported that a dentinal bridge was formed

Indirect pulp capping:
- ▪ Nd: YAG and CO2 lasers are used

- Shoji et al used Co_2 lasers in different WL and reported that no damage was detected in the radicular pulp.
- Charring, coagulation necrosis and degeneration of odontoblastic layer occurred, with no pulp damage resulting in secondary dentin formation
- Irradiated by lasers such as CO2, Nd: YAG and Excimer
- Melting ,resolidification and recrystalisation of the melted areas appear
- A closer look reveals that the melted material resembles glazed interconnected droplets

Pulpotomy

- Shoji et al 1985 performed the first laser pulpotomy using CO2 laser in dogs
- No detectable damage was observed in radicular portions of irradiated pulps with CO2 laser.
- Wound healing of the irradiated pulp seemed to be better than that of controls.
- Wildar- Smith et al 1997 and Dang et al 1998 found CO2 laser pulpotomy to be very successful even in teeth with large exposure sites, subjected to bacterial contamination for several days.

Cleaning & Shaping Of Root Canal System:

- Successful endodontic therapy mainly depends on the elimination of micro-organisms from the root canal system.
- The potential bactericidal effect of laser irradiation can be used effectively for additional cleaning of the root canal system following biomechanical instrumentation.

  Various laser systems emit energy that can be delivered into the root canal system by a

  Thin optical fiber

  Nd: YAG, Er, Cr: YSGG, Ar, Diode

  Hollow Tube

  CO2 and Er:YAG
- It has been demonstrated in many studies that the laser radiation has the ability to remove debris and smear layer from the root canals
- It also has the potential to kill the microorganisms
- Bergman et al suggested that lasers is not an alternative to the conventional cleaning & shaping, but can be used as an adjunct
- Stabholz and Colleagues 2003 developed a new endodontic tip that can be used with an Er:YAG laser system
- The beam of Er:YAG laser is delivered through a hollow tube to allow lateral emission of the irradiation (side-firing)
- This new endodontic side firing spiral tube (RC Lase) was designed to fit the shape and volume of root canal prepared by Ni-Ti rotary instruments.
- Emits radiation laterally to the walls of the root canal through a spiral split located all along the tip.

  Limitations for use in Root Canals
- Emission of laser energy from the tip of optical fiber or the laser when directed into the root canal is not uniform
- There may be thermal damage to the periapical tissues
- May be hazardous when the tooth apex is near vital structures such as mandibular nerve or mental foramen

  Sterilization of root canals:
- The Nd:YAG laser is more popular, because a thin fibre-optic delivery system for entering narrow root canals is available with this device [3]
- Many other lasers such as the XeCl laser emitting at 308 nm (Stabholz et al. 1993), the Er:YAG laser emitted at 2.64 mm (Gomi et al. 1997), a diode laser emitting at 810 nm (Moritz et al. 1997a), and the Nd:YAP laser emitting at 1.34 mm (Blum et al. 1997) have also been used
- All lasers have a bactericidal effect at high power that is dependent on each laser
- There appears to exist a potential for spreading bacterial contamination from the root canal to the patient and the dental team via the smoke produced by the laser, which can cause bacterial dissemination (Hardee et al. 1994)
- Thus, precautions such as a strong vacuum pump system must be taken to protect against spreading infections when using lasers in the root canal (McKinley & Ludlow 1994)
- Sterilization of root canals by lasers is problematical since thermal injury to periodontal tissues is possible

Laser Assisted Obturation:

- Rationale in using lasers for obturation is that the irradiation can be used as a heat source for softening the GP
- Conditioning of the dentin walls can also be done

- The photo-polymerization of camphorquinone-activated resins for obturation is possible using an Ar laser emitting at 477 and 488 nm (Potts & Petrou 1990, 1991)
- The results indicate that an Ar laser coupled to an optical fiber could become a useful modality in endodontic therapy
- An SEM examination revealed that laterally compacted resin fillings showed fewer voids than those obtained by vertical compaction (Kitamura et al, 2005)
- Ar, CO_2, and Nd:YAG lasers have been used to soften gutta-percha (Anic & Matsumoto 1995), and results indicate that the Ar laser can be used for this purpose to produce a good apical seal
- The clinical evidence from reported studies for the use of lasers in obturation is not sufficient
- It has not been determined if the use of laser as a heat source is safe for the surrounding structures of the tooth as well as for other teeth
- A suitable wavelength has not been ascertained
- Effect on the sealer per se has to be determined

Retreatment:

- Rationale for using lasers in retreatment is ascribed to the need to remove foreign material, GP etc by softening it by heat
- Farge et al used the Nd:YAP (1340 nm)
- Attempted to remove GP and ZOE sealer
- They concluded that lasers alone cannot remove all the obturating materials from the RC
- Yu et al were able to remove the entire filling material in 70% cases, while broken files in only 55% of the cases using the Nd:YAG laser
- Removal of GP and files is always a challenge and lasers can only assist
- A clinical advantage is that toxic solvents like xylene can be avoided
- However the effects of the laser on the tissues and surrounding teeth remains to be studied

Lasers in Endodontic Surgery:

- Weichman and Johnson attempted to seal the apical foramen of freshly extracted teeth [4]
- High power CO_2 laser energy was used to irradiate the apices of the teeth
- An eventual “cap” formation due to melting of cementum and dentin was formed but this could be dislodged easily Thus their goal was not achieved
- If Laser is used for the surgery, a bloodless surgical field should be easier to achieve due to the ability of the laser to vaporize tissue and coagulate and seal small blood vessels
- If the cut surface is irradiated, the surface is sterilized and sealed
- The potential of the Er:YAG laser to cut hard dental tissues without significant thermal or structural damage eliminates the need for mechanical drills
- Clinical investigations into laser use for apicectomy began with the CO_2 laser (Miserendino 1988), which was successful
- The use of this laser seals the dentinal tubules in the apical portion of the root and sterilizes the surgical site
- On, extracted teeth (Stabholz et al. 1992 Arens et al. 1993, Wong et al. 1994), used the Nd:YAG laser and found that there was a reduction in the penetration of dye or bacteria within resected roots
- When the laser was used for resection itself, either in extracted human teeth in vitro (Maillet et al. 1996), found that tissue repairs was quicker when compared with those roots resected with a bur
- The main contribution of laser technology to surgical endodontics is to convert the apical dentin and cementum structure into a uniformly glazed area that does not allow egress of micro-organisms through dentinal tubules and other opening in the apex of the tooth.

Advantages:

- Good hemostasis
- Improved visualization of surgical site
- Sterilization operative field
- Reduced permeability of root surface dentin
- Reduction in post operative pain
- Reduced risk of contamination of surgical site by eliminating use of air turbines

Constraints:

- Time Consuming
- Increase temperature
- Cause irreversible pulpal damage
- Needs precise execution
- Increased cost of treatment

Other Endodontic uses:

- CO_2 and Nd:YAG lasers have been used for the attempted treatment of root fractures (Arakawa et al. 1996). However, regardless of the re-approximation technique, laser type, energy, and other parameters used, fusion of the fractured root halves was not achieved [5]
- Lasers (Ar, CO_2, Nd:YAG lasers) have been used successfully to sterilize dental instruments (Adrian & Gross 1979, Hooks et al. 1980, Powell & Whisenant 1991).
- Results indicated all three lasers (Ar, CO_2, Nd:YAG lasers) are capable of sterilizing selected dental instruments; however, the argon laser was able to do so consistenly at the lowest energy level of 1 W for 2 min
- A pulsed dye laser emitted at 504 nm was used for the removal of a calcified attached denticle (Rocca et al. 1994) [6,7]

Etching:

- Laser etching has been evaluated as an alternative to acid etching of enamel and dentine. The Er:YAG laser produces micro-explosions during hard tissue ablation that result in microscopic and macroscopic irregularities
- These micro irregularities make the enamel surface micro retentive and may offer a mechanism of adhesion without acid-etching
- However, it has been shown that adhesion to dental hard tissues after Er: YAG laser etching is inferior to that obtained after conventional acid etching (Martinez-Insua et al., 2000)
- The weaker bond strength of the composite to laser-etched enamel and dentine to the presence of subsurface fissuring after laser radiation. This fissuring is not seen in conventional etched surfaces
- The subsurface fissuring contributed to the high prevalence of cohesive tooth fractures in bonding of both laser-etched enamel and dentine

Caries Prevention

Laser ablation:

- Its defined as the onset of removal of material when increased energy is applied the substance
- Once the light from dental lasers is absorbed it is converted to heat.
- These changes range from denaturation to vapourization and carbonization and even melting followed by recrystallisation in hard tissue
- The selective ablation of caries is possible when the applied energies are at least 0.4 j/cm2 but below 1.8 J/cm2.
- Ablation of dentin was found to be more efficient than the ablation of enamel and depends on the laser fluence.
- Fluence is defined as the total amount of energy applied to a unit of tissue and the total volume of tissue removed by laser [7,8]

Laser Assisted Bleaching:

- Two laser-assisted whitening systems have been cleared by the FDA
- The argon laser wavelength of 488 nm for 30 seconds to accelerate the activity of the bleaching gel
- After the laser energy is applied, the gel is left in place for three minutes, then removed. This procedure is repeated four to six times
- Another system uses both the argon and CO_2 lasers in the bleaching process
- The argon laser is used as previously described, then the CO_2 laser is employed with another peroxide-based solution to promote penetration of the bleaching agent into the tooth to provide bleaching below the surface
- The entire clinical time for this system ranges from one hour to three hours
- Laser-assisted tooth bleaching, however, still poses a number of unanswered questions
- Because of continuing concerns and unknowns about laser interactions with hard tissue and the lack of controlled clinical studies, CO_2 laser-assisted bleaching is not recommended (FDA)
- Based on previously accepted uses of argon lasers and associated temperature-rise studies, the use of the argon laser in place of a conventional curing light may be acceptable if the manufacturer's suggested procedures are carefully followed (FDA) [9,10]

II. Conclusion

- Although lasers have been used in dentistry for many years, clinicians have barely been able to tap the enormous potential of this form of therapy. The decision to use a laser should be based on the proven benefits, rather than claimed advantages. Further laboratory and clinical experimentation may determine a significant place for lasers in the coming future.

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Figure 1

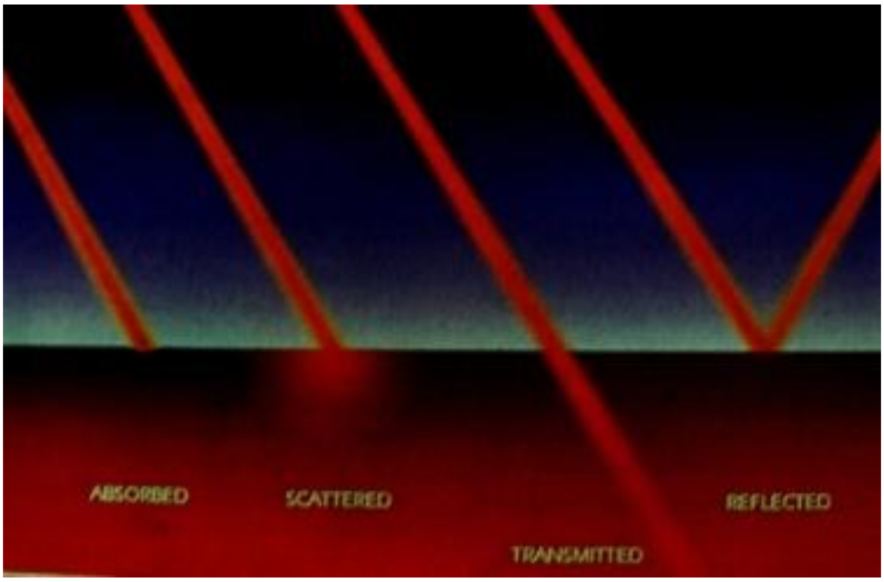

Figure 2