Journal of Current Medical Research and Opinion
Received 05-07-2020 | Accepted 13-08-2020 | Published Online 14-08-2020

DOI: https://doi.org/10.15520/jcmro.v3i08.323
CMRO 03 (08), 579–588 (2020)

ISSN (O) 2589-8779 | (P) 2589-8760

REVIEW ARTICLE

Laser and its Implications in Dentistry : A Review Article

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Abstract
The term LASER is an acronym for 'Light Amplification by the Stimulated Emission of Radiation'. Miaman was the first who introduced laser application in dentistry in 1960 and its hard and soft tissue application. There is lot of advancement in lasers in past two decades. Various hard tissue applications includ caries prevention, bleaching, restorative removal and curing, cavity preparation, dentinal hypersensitivity, growth modulation and for diagnostic purposes, whereas soft tissue application includes wound healing, removal of hyperplastic tissue for uncovering of impacted or partially erupted tooth, photodynamic therapy for malignancies, photostimulation of herpetic lesion. Although lasers proved to be slightly costlier than traditional treatment but it is an effective tool to increase efficiency, specificity, ease and comfort of the dental treatment.
Keywords: Argon, CO2, Enamel, Lasers, Nd : YAG

1 | INTRODUCTION:

Studies in the field of equipment technology has been one of the biggest boons of modern science. Our field of dentistry has been touched in a large way by these latest techonology. Gone are the days of the old belt driven motors to remove caries from teeth. Earlier, motors were used which were replaced by airrotors and now a days air abrasion devices are used. (1) The radiograph

Supplementary information The online version of this article (https://doi.org/10.15520/jcmro.v3i08.323) contains supplementary material, which is available to authorized users.

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is one of the most outstanding examples of how technology change touched the way dental therapy was conceived and carried out.

LASER technology is making great inroads into lot of areas of dentistry. (2) It seems to be all prevalent, right from the smallest laser pointer used by youngsters to have fun, to complex lasers used in medicine to lasers used in stage shows and programs. Lasers have been tried out in dentistry for over two decades but have come into the forefront as an everyday only in the last 3 or 4 years. (3) Latest advancements in technology have found more applications in dentistry. (4)

History (5–7)

Laser history ranges back to modern physics after Einstein's revolutionary concepts and it was practically introduced by Maiman's after 43 years and further 20 years have been necessary to multiply the applications of lasers. The fascination exercised on laser by scientists can be explained by their outstanding characteristics. Some people were convinced that this device was facing a brilliant future; they even foretold that it should be the tool of a major technological breakthrough.

2 | VARIOUS CLASSIFICATIONS OF LASERS (8--10)

I. According to the wavelength (nanometers)

1. UV (ultraviolet) range – 140 to 400 nm

2. VS (visible spectrum) – 400 to 700 nm

3. IR (infrared) range – more than 700 nm

Most lasers operate in one or more of these wavelength regions.

II. Broad classification

1. Hard laser (for surgical work)

i. CO2 lasers (CO2 gas)

ii. Nd:YAG lasers (Yttrium-aluminium-garnet crystals dotted with neodymium)

iii. Argon laser (Argon ions)

2. Soft laser (for biostimulation and analgesia)

i. He-Ne lasers

ii. Diode lasers

III. According to the delivery system

i. Articulated arm (mirror type)

ii. Hollow waveguide

iii. Fiber optic cable

IV. According to type of lasing medium

E.g. Erbium: Yttrium Aluminium Garnet

V. According to type of active medium used

Gas, solid, semi-conductor or dye lasers

VI. According to operation mode

1. Continuous wave lasers

2. Pulsed lasers

VII. According to pumping scheme

1. Optically pumped laser

2. Electrically pumped laser

VIII. According to degree of hazard to skin or eyes following inadvertent exposure

The laser classification system is based on the probability of damage occurring.

Class I : (< 39mw) Exempt; pose no threat of biological damage.

Class II : (< 1 mw) The output could harm a person if they were to stare into the beam for a long period of time. The normal aversion response or blinking should prevent you from staring into the beam. No damage can be done within the time it takes to blink.

Class IIIA : (<500mw) Can cause injury when the beam is collected by optical instruments and directed into the eye.

Class IIIB : (<500mw) Causes injury if viewed briefly, even before blinking can occur.

Class IV : (> 500mw) Direct viewing and specular and diffuse reflections can cause permanent damage including blindness.

Even though there have been many classifications of lasers, Srivastava et al proposed a new simplified classification of lasers based on the clinical use. This classifies lasers on the basis of surgical and non surgical use surgical lasers are subclassified into hard and soft tissue lasers Figure 1 . (8)

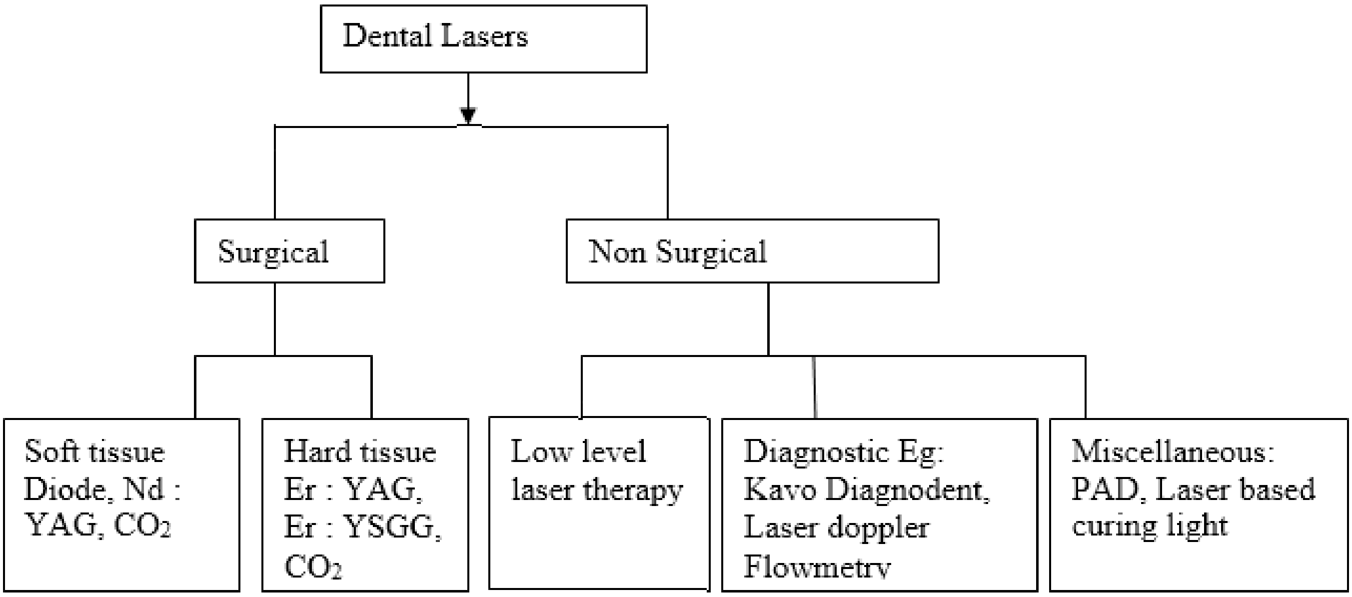

FIGURE 1: Classification of Laser

Non surgical lasers include the diagnostic lasers (Laser fluorescence) (11) , Low level laser therapy, Photo activated disinfection (PAD) (disinfect root canals, periodontal pockets, cavity preparations and sites of periimplantitis) (12) and Laser curing lights has made it easy for the clinician to choose the particular laser wavelength according to his / her clinical requiremnt. (8)

Advantages of this classification (8)

More clinically oriented

The clinician can choose the particular wavelength depending upon what his clinical practice is based upon.

Provides the clinician a simplified overview of a range of lasers available for use in dentistry.

Lasers are becoming an important part of present day dental practice, where they can be used as an adjunct or alternative to traditional approaches.

Details about the individual laser

A) CO_2 Lasers

Patel et al (1964) was the first person to develop CO_2 laser which is a gas laser (2), having a wavelength of 10.6μ or 10,600 nanometers deep in the infrared range of the electromagnetic spectrum. (13) Irrespetive of tissue color, CO_2 lasers show affinity for wet tissues. Since CO_2 laser absorbs water, it generates a lot of heat which readily carbonizes tissues and this carbonized or charred layer should not be removed as it acts as a biological dressing. More than 90% of oral mucosa has water where it is highly absorbed. (14) Penetration depth of 0.2 to 0.3mm occur as it shows high absorption in small volume. (15) CO_2 lasers reflect off mirrors which allows access to difficult areas.

Accidental reflection to non-target tissue is a concern as they also reflect off dental instruments. Easy access to all areas of the mouth are possible because of advances in articulated arms and hollow waveguide technologies. All CO_2 lasers work in a non-contact mode. CO_2 laser is the fastest in removing tissue among all the lasers used for oral cavity. An aiming helium–neon (He-Ne) beam must be used in conjunction with this laser as CO_2 lasers are invisible. (16)

B) Nd: YAG Laser

Nd:YAG stands for neodymium: yttrium-aluminum-garnet and was developed by Geusic et al in 1964. (2) It has a wavelength of 1.064 nm. (17) Low absorption is seen with hydroxyapatite and water. So, the laser power diffuses deeply through the enamel and dentin and finally heats the pulp. (18) Thus, Nd:YAG has various degrees of penetration and optical scattering to the tissue, with minimal absorption and no reflection. (16) It works either by a contact or non-contact mode. (15) The contact mode is highly recommended while working on tissue. Carbonized tissue remnants often buildup on the tip of the contact fiber, creating a 'hot tip'. Nd:YAG laser effect is enhanced by this increase in temperature and it is not necessary to rinse the build up away. (19)

Lateral thermal damage is limited by the use of special tips like the coated sapphire tip. (16) The action of laser is speed up by the use of black enhancer. Nd: YAG laser is used in conjuction with helium-neon with a penetration depth of 2 to 4mm. (20)[20] Superheated gas called plasma can form on the tissue surface at higher powers and pulsing. If not cooled (eg. by running a water stream down the fiber), the plasma can cause damage to the surrounding tissues. (16) This laser is readily absorbed by titanium, amalgam and non-precious metals which require careful operation in the presence of these dental materials. (21)

C) Argon Lasers

This laser is in the blue-green visible spectrum. They operate at 488nm (blue), 496nm (blue/green) or 514nm (green) and the transmission occurs through a flexible optical fiber. (18) This laser shows affinity for dark colored tissues and also for haemoglobin which makes it excellent coagulators. Thus, an argon laser focused on bleeding vessels to the haemorrhage. (22)

It is not absorbed well by hard tissue and no particular care is required to protect the teeth during surgery. (23) There is no reflection in oral tissues, but some scattering, absorption and transmission is seen. Argon lasers have the unique ability to cure composite resins. Blue wavelength (488nm) is used for composite curing while the green wavelength (510nm) is used for soft tissue procedures. (24)

D) Er:YAG laser (Erbium :YAG)

First laser approved by the FDA on May 7, 1997 for use in cavity preparation. Er:YAG laser has the ability to cut or ablate dental hard tissue effectively and efficiently as shown in various researches. (25) With Er:YAG, Pulpal response to cavity preparation was minimal, reversible and comparable with the pulpal response created by a high-speed drill. (26) Er:YAG can also be used for bone ablation and has indications in soft tissue surgeries where no coagulation effect is desired such as removal of hyperplastic gingival tissue, periodontal surgery and ablation of large benign lesions of the oral mucosa and skin. (27)

E) Ho:YAG laser (Holmium:YAG)

Holmium laser is thallium and holmium doped chromium sensitized YAG crystal and has a wavelength of 2,100 nm. These are pulsed lasers and can be used on both contact and non-contact modes like Nd:YAG. Ho:YAG lasers is excellent for arthroscopic temperomandibular joint surgery as it has affinity for white tissues. (24)

F) Helium-Neon Laser

Gas is an amplifying medium made up of helium (85%) and neon (15%). Helium is used as a catalyzer by stabilizing the excited neon atoms at their stimulated levels whereas Neon is the active element. The spectral region is in the visible red i.e. 632nm. Transmission occurs by means of an optical fibre and power ranges from 0.5-50mw. (28)

G) Semiconductor laser (Laser diode)

It is a semiconductor chip (active medium-gallium arsenate) which works like an electrical diode. Diodes have wavelengths in the red and infrared range (0.62 and 1.5μm) which are determined by the operating temperature and semiconductor material. For the making of a diode laser, it is necessary to add a reflective surface at the other end of the junction to establish an optical cavity. These optical cavities are very small (0.05 x 0.15mm). Diode lasers can produce several watts of power even on this scale. (2, 29)

Laser interaction with biologic tissues

Light can interact with tissues in four different mechanisms:

Reflection

Scattering

Absorption

Transmission

Reflection: Reflected laser light is directed outward and bounces off the tissue surface. There is little danger of damage to other parts of mouth as energy dissipates after reflection, which also limits the amount of energy entering the tissue. (30)

Scattering: It is shown by a change in the direction of the radiation without loss of energy. This change in direction is the result of the encounter of the ray with small particles or molecules. The directional character is lost and the irradiated volume becomes larger, dissipating the thermal effects. (18, 30)

Absorption: It is the most important process because it leads to transformations due to the energy supply to the medium. It is responsible for the thermal effects within the tissue that is it converts light. (18)

Transmission: Light may be transmitted through the tissue as if the tissue was transparent. (30)

Application of lasers in dentistry

In Restorative Dentistry

1. Prevention of caries (16, 19)

Yamamoto and Ooya (1974) demonstrated that the lased enamel surface was more resistant to in vitro demineralization than unlased enamel when Nd:YAG laser was used at energy densities of 10 to 20 J/cm^3. It was concluded by Stern that energy levels below 250 J/cm^2 did not alter the pulp permanently.

Lobene and Collogues (1967) and Sirkka Kantola (1973) in their experiments observed that CO_2 irradiation to enamel of the tooth can cause conversion of small amounts of hydroxyapatite to insoluble calcium orthophosphate apatite resulting in decrease in acid dissolution of enamel. In dentin, Sirkka Kantola (1973) showed lased dentin came to closely resemble the hydroxyapatite of normal enamel (due to the increase in calcium and phosphorous contents).

Lasers can be used for removal of incipient caries, sealing pits and fissures. CO_2 and Nd:YAG lasers can remove the organic and inorganic debris found in pits and fissures. Terry Myers (1985) used Nd:YAG laser for debridement of incipient caries. The lased fissure areas appeared similar to that of normal enamel.

After argon fluoride laser, when topical fluoride treatment was performed for conditioning of enamel, significant reduction in enamel acid demineralization was observed.

2. Cavity preparation (16, 18, 23, 30)

The search for a laser that can be used to cut hard tissues began in 1964 by Dr. Leon Goldman who used laser on his brother Bernard's teeth. Successive research included many laser wavelengths such as CO_2 but has disadvantage like cracking with flaking of the enamel surface. Nd:YAG laser inhibit incipient carious lesions at 10 J/cm^2 but at higher densities, can cause irreversible pulpal damage.

Er: YAG has shown most promising results at the wavelength of 2.94mm. Researchers have shown Er:YAG laser's ability to ablate or cut dental hard tissues efficiently and effectively

Pulpal response was minimal, reversible and comparable to a high speed drill with Er:YAG laser in many animal studies. The temperature of laser was less than 3°C and a water coolant can also be used.

Recently Er, Cr:YSGG with a wavelength of 2.97μ has shown to be effective for cutting enamel, dentin and bone. This device create precise hard tissue cuts by virtue of lasers interaction with water at the tissue interface and has been termed as hydrokinetic system or HKS.

3. Etching of Enamel and Dentin (16, 23)

Enamel absorbs the laser thereby causing the enamel surface to be heated to a high temperature, generating micro cracks in the surface which aids in enhancement of adhesion of composite to the tooth structure. The surfaces appear similar to the acid etched surfaces resulting in significant improvement in shear bond strength of resin composites to lased surfaces (Laurence Walsh et al 1994).

Due to its high organic content, etching with dentin results in carbonization or charging which change the structure of dentin. Fungiform projections have been seen and localized melting on the dentinal surface which cause sealing of the dentinal tubules thereby reducing microleakage and enhancing the bond of the final composite restoration. Cooper (1988) and Dederich (1989) have proved this in studies.

4. Curing of Composite Resins (31, 32)

To initiate polymerization, photoactivated dental resins employ a diketone such as camphoroquinone, and a tertiary amine reducing agent. This photoinitiator is sensitive to blue light of the visible spectrum with peak activity in the 480nm region. For the initiation of polymerization of dental resins, the argon laser's monochromatic wavelengths of 488nm and 514nm have been shown to be effective.

Advantages

- Improved physical properties
- Good adhesion
- Decreased microleakage
- Decreased exposure time
- Access to all locations of the cavity preparation
- Light activated bases and liners polymerization can be accomplished with the argon laser

5. Desensitization

Lasers are effective in the treatment of hypersensitivity because of its ability to close dentinal tubules because of its change in hydraulic conductance. (16)

6. Bleaching

Lasers can be used in bleaching of vital and non-vital teeth. (30)

In Endodontics

1)In Root Canal Preparation

Dentin of root canals can be fixed by short exposures of either CO_2 or Nd:YAG laser. As a result, the fused dentin crystallize into a glazed, non-porous surface, which used in decreasing dentinal permeability following root canal obturation. After plugging filling materials in the root canal, it can be used into a continuous non-porous surface, as it allows little microleakage. (33)

2) Sterilization of Instruments

Adrian JC and Gross A have used CO_2 lasers for sterilization of files, reamers and for surgical instruments, which has been proved in 1979. Hooks et al (1980) exposed contaminated endodontic reamers to CO_2 laser beam. 100% contaminating spores were killed by laser. Argon laser sterilized the selected dental instruments which were tested at the lowest energy level. (34)

3) The laser apicoectomy

Endodontic application of the CO_2 laser for periapical surgery was studied by Leo J Miserendino (1988). He found that out it has several advantages like improved haemostasis, potential sterilization of the infected root surface and apex and reduced risk of contamination of the surgical site by elimination of the aerosol producing air turbine handpiece. (35)

In Pediatric Dentistry

1. Frenectomy and Ankyloglossia

In an attempt for diastema closure, a laser-assisted frenectomy could be done with Er: YAG laser when hyperactive labial frenum is present. It is also used for surgical management of ankyloglossia or severe tongue tie in infants and children (30, 36) .

2. Exposure of Unerupted Tooth

Er: YAG, Nd:YAG, and Er-Cr: YSGG lasers are used to expose a unerupted or partially erupted tooth for orthodontic bracket or button placement. (30)

3. Pulpotomy of Primary Teeth

Pulpotomy of primary teeth using didode laser showed 100% success rate after 1 year follow-up and proved to be a better alternative than ferric sulfate and electrosurgery clinically and radiographically. Jeng-fen Liu et al (1999) evaluated the effects of laser pulpotomy in primary teeth and found all the teeth irradiated with laser were clinically successful in a 6 months follow-up visit except one. (30, 37)

4. Direct and Indirect Pulp Capping of young Permanent Teeth

CO_2 laser is used for direct pulp capping as it controls hemorrhage and sterilizes the exposure site which facilitates better placement of calcium hydroxide paste at exposure site and induces favorable clinical outcome. Laser irradiation is usually performed at a power of 1–2 W. (37)

5. Pediatric Crown Preparation

For pediatric crown preparation, biolase is used. Crowns are prepared with the same specification as used in the conventional method and it is set at 5.5 W with 65% air and 55% water. Patient comfort is improved as the need of local anesthesia has been eliminated by this method. (38)

6. Prevention of Dental Caries

Erbium or CO_2 laser increases caries resistance when used for treatment of enamel surface of a newly erupted tooth. CO_2 laser at 10,600, 9600, and 9300 nm and Erbium laser at 2940 and 2780 nm wavelength produces the same result. Argon laser when used in conjunction with topical fluoride application reduces caries attack much more effectively than argon laser alone. (30)

In diagnosis

D. Benedelto and D.E. Antonson (1988) described that using CO_2 lasers can be used to detect incipient carious lesions, which cannot be detected clinically or radiographically. Laser-induced fluorescence has been used in the assessment of caries. Lesion appears as a distinct dark red area which can be easily differentiated from the sound tooth structure. Area of decalcification appear as a dull, opaque, orange color. Using this technique enamel fractures and recurrent decay around metallic and resin restoration can also be diagnosed. (39)

Laser Doppler Flowmetry has been used for vitality testing of the teeth. By stimulating nerve endings, electrical vitality testing devices work but blood circulation in the pulp is detected by flowmetry which is much more reliable and comfortable to the patient. (40)

In Periodontics

For the benefits of bacteria reduction, bacteremia control, efficient subgingival calculus removal (using Er: YAG lasers) and improvement of periodontal regeneration in animals and humans without damaging the surrounding bone, better removal of the pocket epithelium in the pockets and pulp tissues. lasers in periodontal therapy have been demonstrated. (13)

1. Removal of Pocket Epithelium

The first laser wavelength for the comparison with scalpel for treating periodontal pockets and controlling bacteremia and gingival bleeding was the Nd : YAG. (41) Clinical evaluation of soft tissue biopsies taken from human subjects using the Nd: YAG laser versus a curette presented a complete removal of the epithelium of the pocket after use of the pulsed Nd: YAG laser compared to the curette. (13) Israel et al (1995) histologically demonstrated the effects of de-epithelialization technique in humans. CO_2 laser was used in the technique to remove (ablate) the inner part of flap after conventional periodontal flap elevation and same method is used in the outer part of the flap to achieve epithelial retardation. (42)

2. Laser root conditioning

Barone et al (2002) showed that smooth and clean root surfaces can be created with a defocused, pulsed CO_2 laser when compared to a focused, continuous wave as the latter leads to melting and root surface damage. (43) Several studies used the same parameters for CO_2 lasers had shown root conditioning with a better fibroblastic activity, greater fibroblast attachment and cellular proliferation. (13)

3. Bacterial reduction

Assaf et al (2007) (44) when used a diode laser in conjunction with ultrasonic scaling for treatment of gingivitis, they show a significantly lower incidence of bacteremia in the diode + ultrasonic group (36%) compared to the ultrasonic only group (68%). It was suggested that to prevent bacteremia, especially in immuno-compromised patients, diode lasers should be used. Kamma et al (2009) (45) confirmed that the total bacterial load in pockets can be reduced without use of any systemic antibiotic therapy.

In Implant Dentistry

Lasers can be used in implant dentistry for second stage surgery, removal of peri-implant soft tissues and decontamination of failing implants. Serious concerns related to implant overheating followed by melting of the implant surface have been raised, along with lack of re-osseointegration following treatment of peri-implantitis with lasers. (13, 46) A significant temperature increase of the implant surface has been demonstrated when irradiating implant surfaces with a diode laser in vitro for more than 10s. (13)

3 | CONCLUSION:

Laser technology has shown high state of refinement for hard tissue application and soft tissue surgery during several years of development till the present time and further improvements can also be made. In the dentistry, laser is a blessing being a non invasive approach. In future, emphasis should be laid upon for combination of diagnostic and therapeutic laser techniques. It can be expected that laser technology will become essential components of contemporary dental practice over the next decade.

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How to cite this article: Maheshwari S., Jaan A., Vyaasini C.V.S., Yousuf A., Arora G., Chowdhury C. Laser and its Implications in Dentistry : A Review Article. Journal of Current Medical Research and Opinion . 2020;579−588.
https://doi .org/10.15520/jcmro.v3i08.323