Lasers in Pediatric Dentistry: A Review Article

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Abstract

Laser applied science has been newly introduced into the dentistry to substitute drilling. The 1st dental experience for pediatric patients using laser can be useful from the point of preventive & therapeutic approach. This article approached to educate about laser physics, its components, fundamentals, mechanism of its action, applications, advantages,disadvantages, laser safety & medico-legal aspects of laser specifically concerning pediatric dentistry. Due to their minimal invasion, treatment by laser is well accepted by children. The use of scalpels conventionally, may produce post-operative discomfort & thus, prolonged wound healing. Being safe in use, lasers are an important in-office alternative to treat pediatric dental patients. Hence, lasers use enhances the children's cooperation leading to greater satisfaction by all three i.e. guardians,patient & dentist.

Keywords: *Pediatric laser dentistry; Laser dentistry, minimally invasive approach.*

Introduction

The therapeutic use of light is being used from centuries. LASER is "Light Amplification by Stimulated Emission of Radiation".[1] In 1916 when physicist Albert Einstein explained the stimulated emission theory, the principle of laser came into light.[2] It is an electromagnetic energy with unidirectional and monochromatic unique properties. Today laser has found endless uses in many disciplines of medicine & dental surgery. Laser can serve as a favorable option due to less pain, sound & vibration. Lasers were 1st used for soft tissue incision. The new types of lasers' work on water molecules can be used for the ablation of hard dental tissue as well. It's been used in different fields of dentistry as it has wide applications. Laser is a promising arena towards the "minimally invasive", modern pediatric dental treatments. In the present scenario, the laser provides a safe & effortless alternative for treating children in dentistry. Then dental visit becomes a lot easier for patient, parents, and dentist. Children seem to be more cooperative during dental procedures using lasers, which boost up the quality of care & the method of treatment.

History: A **MASER** is a device that stands for "**Microwave Amplification by Stimulated Emission of Radiation"**, which produces "coherent electromagnetic waves through amplification by stimulated emission & was built by Charles H. Townes, James P. Gordon, and Herbert J. Zeiger at Columbia University in 1953". The laser works by the same principle as the maser, but produces "higher frequency coherent radiation" at visible wavelengths. In 1960, LASER was made from a laser device "known as ruby laser," invented by Theodore Maiman which stands for "Light Amplification by Stimulated Emission of Radiation". Gordon Gould is credited with creating this acronym in 1957.[3] The first application of the laser was used for skin problems diagnosis & treatment and later used in endoscopic surgery & ophthalmology.[4] In ***1965*** "*Stern & Sognnaes's* detailed about this "*ruby laser* "in their study that it could *vaporize enamel* & also thermally *affects* the pulp of the tooth.[5] Patel invented CO_2 *laser* in 1964 that had both soft tissue & hard tissue applications.[6]

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In ***1964***Nd: YAG laser was introduced *by* Geusic which remain unnoticeable until 1990. The 1st usage of laser in 'endodontics' was shownby "*Weichman & Johnson"* in the year of 1971*,* for the apical foramen seal, in vitro, by utilizing CO_2 laser.[6] Studies are carried out for future indications. Since then, the clinical applications of lasers continue to increase indentistry.

Laser Physics: A laser machine forms *multiple atoms* that pump out *multiple photons (known as light particles*) all of which line up to form a *concentrated light beam*. Matter consists of *atoms*. Nucleus lies at the center of the atom; which contains *protons & neutrons*. A (+ve) charged is a proton & neutron is neutral. Outside the atom are *electrons* which are (-ve) charged and they are in motion surrounding the nucleus. The conversions are of 3 types which are as follows:[7,8]

1. **Spontaneous Absorption:** In this, an electron alter state to higher state from lower state by absorbing a photon (Figure. 1a)
2. **Spontaneous Emission:** In this, an electron spontaneously releases a photon to shift it to a lower state from a higher state (Figure. 1b)
3. **Stimulated Emission:** In this the electrons transit to a lower state from higher state & release a photon. The incident photon & their released counterparts possessa similar wavelength. This particular wavelength correlates with the energy difference between the two orbits.(1c)

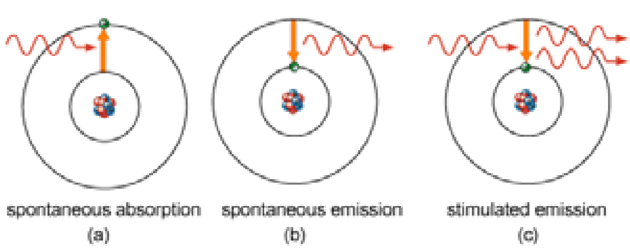

Figure 1. Concentrated light beam (3 types of conversions)

The characteristic of laser-produced from stimulated emission are as follows:[9,10]

1. **Monochromatic:** Single wavelength light is produced.
2. **Coherent:** All photons show similar polarization & produce a very high intensity when they superpose.
3. **Collimation:** It depicts a narrow & powerful emitted laser beam which consists of constant shape & size.
4. **Efficiency:** At low energy state lasers produces the required energy to carry out their specified function.

Amplification: The process of amplification takes place within the laser device. The laser machine consists of a core that is known by the optical cavity that comprises of chemical elements, molecules/compounds which are known by 'active medium'. Lasers are termed after the active medium material, such as after a gas, semiconductor, etc. The optical cavity has two ends. Each end has one mirror which is placed parallel to one another. An electrical coil/Flash lamp is the excitation source for active medium.

Stimulated Emission: In 1900 *Max Planck* introduced the 'quantum theory of physics' which later forms the basis for stimulated emission. Albert Einsteinstated that an "additional quantum of energy traveling in the field of the excited atom that has the same excitation energy level would result in a release of two quanta, a phenomenon defined stimulated emission". These photons further energizes more atoms & it results in the population inversion that causes an increase in numbers of the atoms of the active medium from resting state. And to maintain this excitation, a pumping mechanism is required. At the two ends of the active medium, two mirrors are placed which reflect photons back & forth for further stimulated emission. This consequence travels through the active medium which raises the photon beam power & thus gets amplified.

Radiation: It is the light waves emitted as a distinct form of electromagnetic energy. The short wavelengths, below 300 nm, are described by ionizing radiation. The higher photon energy can penetrate biologic tissue easily & reproduces charged atoms. Wavelengths more than 300 nm possess less photon energy & results in excitation. Thus, it heats the tissue with which they interact. The currently used lasers in dentistry have wavelengths from 500 nm to- 10,600nm.

Fundamentals of Laser: Oral tissues have a distinguishing affinity for absorbing laser energy of specific wavelengths. Hence, the selection of a laser depends on the target that is to be treated. The optical aspect of target tissue forms the basis of laser light interaction in different ways with the intended tissue. These interactions are as follows:[11,12]"

a. **Transmission:** *Laser* energy is transmitted directly through the target tissue without effecting target tissue.

b. Reflection: This property of laser used for diagnostic purposes. It redirects itself off the surface. It is useful for measuring the 'sound tooth structure' in dental caries.

c. Absorption: There is the absorption of laser energy in the target tissue on the application of laser on tissue. Different laser wavelengths have a "different absorption coefficient" with the dental tissue components.

"Lasers primarily interact with dental structures photothermally. The temperature of the target tissue increases as laser light is absorbed & when the tissue reaches 100°C temperature, the intercellular & intracellular H_2O (water) boils, which induces both soft tissue vaporization or likely to explode & disarrange 'hard tissue' (*ablation*).With the continued increase in temperature of 200°C,the tissue gets dehydrated & later burned in the presence of the air (*carbonization*). Carbon is the end product & it absorbs all wavelengths".[13-15]

Laser-Component:

All lasers have the six components which are listed below: Figure 2.

1. Active medium- Materials in the core of the laser, can be gas, solid, liquid, or crystals.
2. Pumping mechanism-It is a primary source of energythatis absorbed by the active medium, that results in the "production of laser".
3. Optical resonator- It has a two-mirrorsystem (one is completely reflective & the other one is selectively transmissive) which amplifies and collimates the developing laser beam.
4. Cooling subsystem- It cools down the heat produced by a laser.
5. Controller subsystem (microprocessor)-It is responsible for controlling power output variation to time.
6. Delivery system- It is dependent on the wavelength emitted."

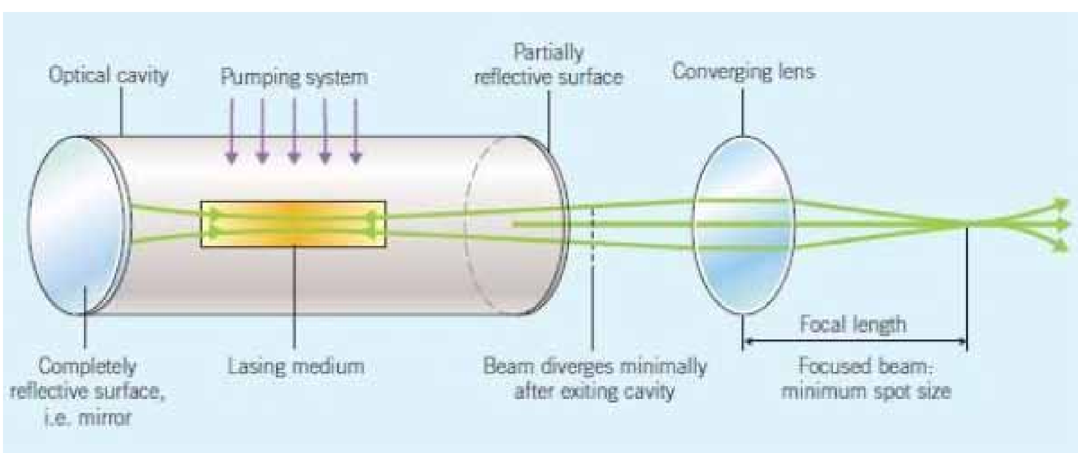

Figure 2. Laser-Component

Various Laser Delivery System: Earlier most dental lasers were having bulkier articulated arms for their delivery systems. But each laser has a distinctive delivery system such as handheld laser, fiber delivery system,articulated arm deliver system & hollow tube delivery system.

Classification of Laser:

"Lasers have been classified in many ways such as[16,17]:

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/more than one wavelength region.

II. Broad classification

1. Hard laser (for surgical work)
   i. CO_2 lasers (CO_2 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 laser ii. Diode lasers

III According to the type of active medium used:

a. Gas lasers:
   - Argon • Carbon-dioxide

b. Liquid:
   - Dyes

c. Solid:
   - Nd:YAG
   - Erbium: yttrium aluminium garnet (Er: YAG)
   - Diode

d. Semiconductor:
- Hybrid silicon laser

e. Excimers:
   - Argon-fluoride
   - Krypton-fluoride
   - Xenon-fluoride

IV. According to pumping scheme

1. Optically pumped laser
2. Electrically pumped laser

V. According to operation mode

1. Continuous-wave lasers
2. Pulsed lasers

VI. The laser classification system is based on the possibility of damage occurring-

- Class I (< 39mw):No threat.
- Class II (< 100 MW): It could harm a person if he stare into the beam for a long period. The normal aversion response or blinking should prevent from staring into the beam.
- Class III (500mw): It causes permanent damage including blindness.

VII. Based on clinical use

1. Surgical: i. Hard tissue; ii. Soft tissue
2. Non-surgical: i. Diagnostic; ii. Low-level therapy; iii. Miscellaneous photo-activated disinfection laser-based curing light"

Wavelengths Used in Pediatric Dentistry:

Table 1. On basis of active medium, wavelength, clinical uses laser are named accordingly

"Argon laser	**Active medium-**Argon gas **Wavelength used**-488nm (blue) & 514nm (blue green). **Clinical applications-** – Caries detection. – Polymerization of light-activated composite resins, dentin bonding agents, sealants, bleaching gels, light-activated impression materials.
Diode laser	**Active medium-**GaAlAs,InGaAs(semiconductor) **Wavelength used**- 655nm, 800-830nm & 980nm. **Clinical applications-** – Cutting & coagulating gingiva and oral mucosa. – Sulcular debridement.

Laser-Nd:YAG	**Active medium-**A solid garnet crystal combined with rarerare earth elements yttrium & aluminumdoped with neodymium ions. **Wavelength used-**1064nm **Clinical applications-** – Cutting & Coagulating dental soft tissues. – Sulcular debridement
Laser-Ho:YAG	**Active medium-**Solid crystal of YAG sensitized with Cr doped with holmium & thulium ions. **Wavelength used-**2100nm **Clinical applications-** – Used frequently in oral surgery for arthroscopic surgery on the TMJ. – It has many medical applications.
Laser-Carbon dioxide	**Active medium-**A mixture of CO_2, He & nitrogen gases in proportions of 8:7:1. **Wavelength used-**9300nm,9600nm & 10600nm. **Clinical applications-** – Soft tissue procedures such asgingivectomy,gingivoplasty,biopsy, frenectomy. – Coagulation after completion of surgery.
Laser-Erbium family	**Active medium-** Solid crystal of YSGG doped with Er Cr. & solid crystal of YAG doped with Er. **Wavelength used-**2780nm & 2940nm. **Clinical applications-** – Caries removal & cavity preparation. – Bone removal. – Vital & non-vital pulp therapy. – Tissue retraction for uncovering implants.”

Role of Laser in Pediatric Dentistry[18-20]: It contributes to providing a positive dental experience with reduced fear and anxiety for the pediatricpatient. Due to its less invasive nature,children are more cooperative during treatment.

Advantages in Pediatric Dentistry:

1. No anesthesia, no drill
2. Less blood loss.
3. Reduce post-operative edema.
4. Initial healing, rapid regeneration, reduce post sensitivity in restorations
5. Suture, dressing are not required.
6. Less chances of metastasis
7. Sterilization of treatment site.
8. Tooth enamel is less exposed,results in a decrease in caries progression.
9. The patient becomes free of fear & anxiety.
10. Beneficial for medically compromised patients.

Disadvantages:

1. Direct light or reflected light both can harm the eyes of the practitioner as well as the patient.
2. The laser is quite expensive.
3. Need qualified personal.
4. Dental hand-pieces required for finishing, after cavity preparation by laser. Also, it should not be used to fill the cavities present between teeth.
5. It should not be used for the removal of silver restoration or damaged crowns.
6. The possible risk of viral disease transmission from “aerosol” in immune-compromised patients.

Applications

Soft Tissue Laser Uses

1. **Frenectomy and treatment of ankyloglossia:** The abnormally joined frenum on the maxilla/ hyperactive labial frenum both are the cause of spacing between teeth, poor oral hygiene, gingival retraction & continuous trauma during brushing.

Also, the situation with the short & hypertrophic lingual frenum (ankyloglossia) is common in new-borns, which results in remarkable problems in breastfeeding, swallowing & phonation.

2. **Gingival recontouring, gingivectomy, bone surgery & crown lengthening:** In children with gingival hypertrophy, tooth decay that propagated under the gingiva, the laser can be used. It is also used for the gingivectomy, limiting the use of anesthesia. The YSGG was 1st laser used for the bone surgery & crown lengthening to correct deformity & create required the physiologic osseous contours.

3. **Exposure of unerupted tooth & treating pericoronal problems in erupting teeth:** To expose an unerupted or partially erupted tooth for orthodontic bracket or button placement, laser is used.Lasers are used to expose the clinical crown of the involved tooth.

4. **Pulpotomy, pulpectomy of primary teeth using laser:** Laser takes 10s-20s to work in a vital tooth. In non-vital teeth, the laser's success rates are almost the same as that of conventional pulpotomy procedures. In 1999, Jeng-fen Liu *et al.* evaluated the effects of laser pulpotomy in primary teeth and found it clinically successful in a 6 months followup visit except one.

5. **Direct, indirect pulp capping of young permanent teeth using laser:** 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 the exposure site. Laser energy has an obtundent and sedative effect on inflamed pulpal tissue which led to its use in indirect pulp capping procedure.

6. **Laser in wound healing:** Low-level laser treatment promotes wound healing.

7. **Laser in diagnosing pulp vitality:** Laser Doppler flowmetry is a non-invasive method of diagnosing pulp vitality.

8. **Laser in disinfection of root canal:** Laser used in root canal disinfection during root canal treatment and irrigation of the canal with 5.25% sodium hypochlorite or 14% EDTA is carried out during laser irradiation.

9. **Laser in tooth bleaching:** When the laser light hits bleaching gel, it produces heat thus the oxidation process becomes accelerated resulting in the whitening of the tooth surface.

10. **Laser in pediatric tooth preparation:** Biolase is used for pediatric tooth preparation. This eliminates the need for local anesthesia & increases the micromechanical bonding with resin cement as it producesmore roughness on prepared tooth surfaces.

11. **Hypertrophic lesions:** Diode laser is particularly recommended in oral soft tissue surgery, specifically regarding benign lesions.

12. **Lasers used in pain management:** "LLLTdrop the concentration of chemical agents such as histamine, acetylcholine (Ach) etc., all of them are pain mediators. They inhibit the concentration of ACh, a pain mediator, through increased acetylcholine esterase activity & hence, used for the treatment of dentin hypersensitivity."

13. **Herpes Labialis & Recurrent Aphthous ulcers:** Laser brings immediate relief to the "aphthous ulcer" lesion or shorten the duration of the" herpes labialis" lesion.

Hard Tissue Uses:

1. **Removal of caries, old restoration, and cavity preparation:** Lasers are used for carious tissue removal, results in the preservation of tooth-healthy tissues.Cavity preparation with the use of laser in children for enamel & dentin removal seems very reasonable, because it eliminates the injury to lip, tongue due to lip bite & tongue bite which are frequent problems with children.

2. **Pit and fissure sealants:** The lasers can clean & sterilize the enamel fissures. Laser can be used for fistulotomy, cleaning & conditioning of pits & fissures before sealant application.

3. **Diagnodent and caries detection:** Diagnodent is the device has also the ability to show decays in early stages that are not seen in radiographs. Laser fluorescence at a wavelength of 655 nm is effectively used for the detection of occlusal hidden caries and occult lesion in primary and permanent teeth.

4. **Prevention of dental caries:** Laser heat effects and the creation of micro openings and small cracks facilitate the penetration of fluoride. It seems that the simultaneous use of laser & fluoride is the best method of carious lesions prevention.

Dental Laser Safety[21,22]:

The aspects of laser safety are:

1. The assembling procedure of the laser instrument,
2. Right mechanism of the device &
3. Personal protection of patients as well as operating squad from laser.

Medico-Legal Aspects of Laser in Dentistry[23]: Conventional soft tissue surgery with a dental laser is accepted in dentistry & covered under insurance policies. Informed consent must be routine & a part of the general consent form that all patients, guardians read & sign before the start of dental treatment. It is highly suggested that each practitioner take a course."

Conclusion

Its use in pediatric dental procedures is well accepted. Its minimal invasiveness allows pediatric patients to be cooperative during dental procedure. Lasers in dental practice present remarkable accuracy, pain-free, quick healing & safety. Although its effectiveness in the diagnosis of dental caries, prevention of caries, endodontic management of deciduous and permanent teeth, and different softtissue procedure is well documented, further research regarding its efficacy in pediatric dental procedure is still needed.

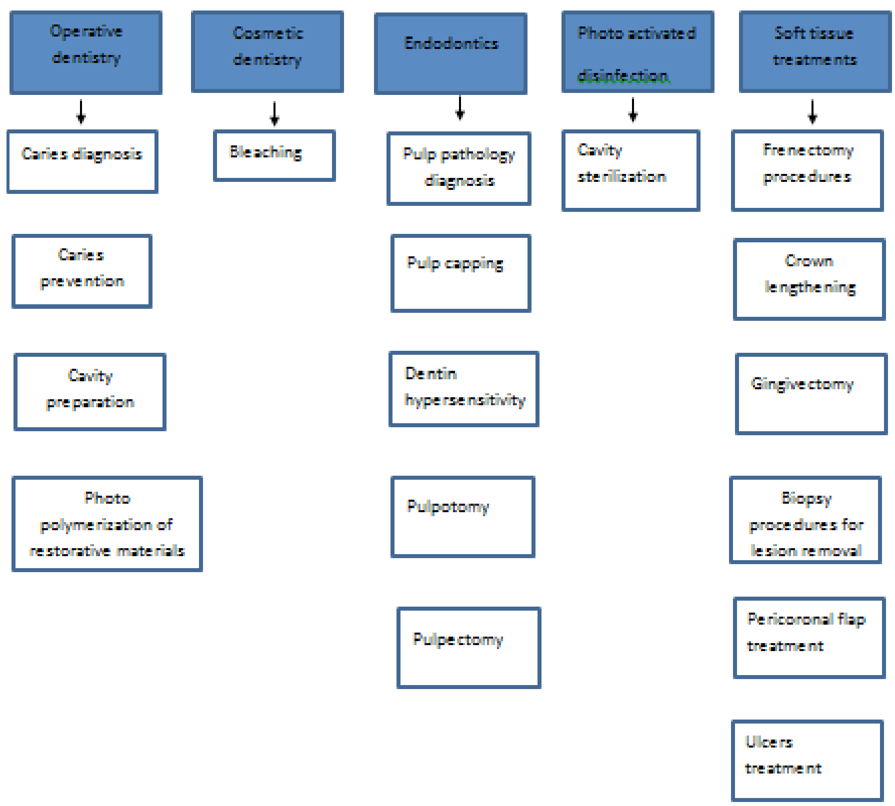

Figure 3 Use of lasers in pediatric dentistry

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