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Lasers in endodontics review

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Abstract---Lasers have been a significant advancement in the field of endodontics. Be it effective cleaning, root canal treatment, surgery etc. The lateral accessory canals and anatomical complexities have been a restraint in root canal procedure, for such cases lasers have been introduced to simplify the process & have good clinical results. As there has been a boon in the improvement of laser techniques, many latest lasers having a broad array of characteristics is accessible and can also be helpful in several areas related to dentistry. When compared with conventional techniques, laser treatments have been proven to be more advantageous. The purpose of this article is to

summarize laser applications in endodontics, including their use in pulp diagnosis, dentinal hypersensitivity, pulp capping and pulpotomy, sterilization of root canals, root canal shaping & obturation & apicectomy. This article reviews the role of lasers in endodontics since the early 1970s & summarizes what future may hold for endodontics. With the potential availability of many new laser wavelengths and modes, much interest is developing in this promising field.

Keywords--dentine, laser diagnosis, laser therapy use, root canal treatment.

Introduction

Since the ruby laser was developed by Maiman (1960). Researchers have investigated laser application in dentistry. A laser is a device which 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. Stern & Sognnaes (1964) and Goldman et al. (1964) were the first to investigate the potential uses of the ruby laser in dentistry. They began their laser studies on hard dental tissues by investigating the possible use of a ruby laser to reduce surface demineralization. Indeed, they did find a reduction in permeability to acid demineralization of enamel after laser irradiation.

After initial experiments with the ruby laser clinicians began using other laser such as argon (Ar) carbon dioxide (CO₂) neodymium: yttrium-aluminium-garnet (Nd:YAG) and erbium (Er): YAG lasers. The first laser use in endodontics was reported by weichman & Johnson (1971) who attempted to deal the apical foramen in vitro by means of a high power-infrared (CO₂) laser. Although their goal was not achieved sufficient relevant and interesting data were obtained to encourage further study. Subsequently attempts were made to seal the apical foramen using the Nd:YAG laser (Weichman et al. 1972). Although more information regarding this laser's interaction with dentine was obtained the use of the laser in endodontics was not feasible at that time. Since then, many papers on laser applications in dentistry have been published (Midda & Renton-Harper 1991. Pick 1993. Wigdor et al. 1993 .1995), Many papers have been published on endodontics applications and much information has been gathered. Nevertheless, in dentistry and in endodontics in particular acceptance of this technology blurs the border between technical biological and dental research. The purpose of this paper was to summarize laser applications in endodontics.

History of Lasers in Dentistry

History Of Lasers in Dentistry The most recent development in endodontic treatment is the use of lasers. Since the development of the ruby laser by Maiman in 1960. Dental researchers began investigating lasers potential and Stern and Sognnaes reported in 1965 that a ruby laser could vaporize enamel.^[1] The first laser use in endodontics was reported by Weichman& Johnson (1971) who

attempted to seal the apical foramen invitro by means of a high powerinfrared (CO₂) laser. Subsequently, attempts were made to seal the apical foramen using the Nd:YAG laser.Practitioners and researchers began to find clinical oral soft tissue uses of medical CO₂and Nd: YAG lasers until in 1990 when the first pulsed Nd: YAG laser designed specifically for the dental market was released. The year 1997 saw the FDA clearance of the first true dental hard tissue Er: YAG laser and the Er, Cr: YSGG a year later. Semiconductor based diode lasers emerged in the late 1990s as well.

Mechanism of Action of Lasers

The word laser is an acronym standing for –Light Amplification of Radiation|. A laser beam is created from a substance known as an active medium, which when stimulated by light or electricity produces photons of a specific wavelength. Lasers are characteristically monochromatic, unidirectional, coherent, and emitted from a stimulated active medium. Monochromacity means that a laser beam is made of a single wavelength of light, and all dental lasers are found in the visible or infrared portion of the electromagnetic spectrum. Once a laser beam is produced it will travel in one direction (unidirectional), though the divergence of the beam varies by type of laser and the associated transmission hardware. Coherence is the property that not only is a laser a single wavelength but all the peaks and valleys of each wave travel in unison.

The active media in dentistry can be solid state, gas, or semiconductor. Solid state lasers are a crystal matrix host doped with the light emitting, excitable atoms; such as erbium laced yttrium, aluminium, and garnet (Er: YAG). CO₂is a popular laser where the active medium is sealed in an air tight chamber. Diode lasers have a semiconductor that when stimulated with electricity, laser light is emitted [2] Stimulated emission is a phenomenon that occurs within the active medium. For example, in solid state Er: YAG lasers the erbium is stimulated by light from a flash lamp with a process known as optical pumping. As an erbium atom absorbs a photon, its electrons are elevated to higher energy level. When the electrons return to a lower energy state, two identical photons are emitted and these photons can further stimulate more atoms in a chain reaction, resulting in amplification of the light produced. Mirrors surrounding the active medium called a resonator further increase this light energy. One of the mirrors called the output coupler is less than one hundred percent reflective. Light leaks from the output coupler and these are the photons that form the laser beam. Once the beam is created it is carried to the target tissue by various types of beam transfer hardware. Mirrors in articulated arms and optical fibers are common examples of this hardware [3] Different lasers considered for endodontic applications are the near infrared laser—diode (810, 940, 980 and 1,064 nm) and Nd:YAG(1,064 nm)— and the medium infrared lasers—Erbium,Chromium: YSGG (Er,Cr:YSGG; 2,780 nm) and Erbium:YAG (2,940 nm).

Near infrared lasers such as Nd:YAG (from 803 nm to 1,340 nm) were the first to be used for root optical fibre. The near infrared lasers are not absorbed by hard dentinal tissues and have no ablative effect on dentinal surfaces. The thermal effect of the radiation penetrates up to 1mm into the dentinal walls, allowing for a decontaminating effect on deeper dentine layers. The medium infrared lasers,

such as the Erbium (2,780 nm and 2,940 nm) laser family, with flexible, fine tips have also been used. The medium infrared lasers are well absorbed by the water content of the dentinal walls and consequently have a superficial ablative and decontaminating effect on the root canal surface. The far infrared laser CO₂ (10,600 nm) was the first to be used in endodontics for decontamination and apical dentine melting in retrograde surgery. It is no longer used in this field with the exception of vital pulp therapy (pulpotomy and pulp coagulation).

Applications Of Lasers In Endodontics

- Lasers as a Diagnostic Tool for Endodontics
- Analgesic Effects of Laser
- Laser & Dentin Hypersensitivity
- Treatment of vital pulpal tissue-Pulpotomy and Direct pulp capping and pulp amputation
- Root canal disinfection and irrigation-
 - Access cavity preparation and root canal orifice enlargement.
 - Root canal wall preparation.
 - Sweeping of Root canal and irrigation.
 - Sterilization or disinfection of infected canals.
 - Obturation with gutta percha or resin.
 - Removal of temporary cavity sealing materials, root canal sealing materials, and fractured instruments in root canals
- Vertical root fracture diagnosis and treatment
- Laser Assisted Obturation and removal of gutta percha obturation material.
- Endodontic surgery-
 - Flap preparation – incision of soft tissue to prepare a flap and expose the bone.
 - Cutting bone to prepare a window access to the apex (apices) of the roots
 - Apicoectomy – amputation of the root end
 - Root end preparation for retro fill amalgam or composite
 - Removal of pathological tissues (i.e., cysts, neoplasm or abscess) and hyperplastic tissues (i.e., granulation tissue) from around the apex.

Laser & Dentin Hypersensitivity

The use of lasers in endodontics has been studied since the early 1970s, and lasers have been more widely used since the 1990s. A successful endodontic therapy is when there is complete and effective cleaning of root canal.^[4] Traditional endodontic techniques use mechanical instruments, as well as ultrasound and chemical irrigation to shape, clean and completely decontaminate the endodontic system. There is limitation of endodontic therapy such as lateral canals with various morphologies and dimensions.^[5] The usefulness of the debridement, cleaning and refining of the intra-radicular space is limited, because of anatomical complexity and the difficulty of common irrigants to penetrate into the lateral canals and the apical ramifications. Hence, there is need for new materials, techniques and technologies that can improve the cleaning and decontamination of these anatomical areas.^[6]

Different wavelengths have been shown to be effective in significantly reducing bacteria in infected canals and studies have confirmed these results in vitro. Further studies have demonstrated the efficiency of lasers in combination with commonly used irrigants, such as 17% EDTA, 10% citric acid and 5.25% sodium hypochlorite.^[7] The action of the chelating substances facilitates the penetration of laser light, which can penetrate into the dentinal walls up to 1mm in depth and have a stronger decontaminating effect than chemical agents. Laser-activated irrigation, has been shown to be statistically more effective in removing debris and the smear layer in root canals compared with traditional techniques and ultrasound. ^[8] A recent study by DiVito et al. demonstrated that the use of the Erbium laser at sub-ablative energy density using a radial and stripped tip in combination with EDTA irrigation results in effective debris and smear layer removal without any thermal damage to the organic dentinal structure. In endodontics, lasers use the photo- thermal and photomechanical effects resulting from the interaction of different wavelengths and different parameters on the target tissues. These are dentine, the smear layer, debris, residual pulp and bacteria in all their various aggregate forms.

Laser Wavelength Consideration ^[9]

The primary use of lasers in endodontics is focused on eradicating microorganisms in the root channel, especially in the lateral dentinal tubuli. This requires a wavelength that shows high transmission through hydroxyapatite and water. Absorption curves show that Nd:YAG lasers, and in particular pulsed Nd:YAG lasers, are first-choice for this application. Nd:YAG lasers show the best results in transmission and microorganism reduction measurements.

Thermal Consideration

Behrens and Gutknecht, 1993, ^[10] conducted in- vitro experiments on dentine slices with laser power settings that take into account even the most extreme situations, in order to determine that no thermal damage occurs in pulsed Nd: YAG laser or diode laser treatments. When measuring the root surface, a temperature of 38° C was obtained after a 45-second treatment duration at 15Hz/1.5W. This value lies within the physiological area. It must be considered that in an in-vivo situation the dental tissue is more efficiently cooled by the blood flow that surrounds the root surface.

Morphological Changes

The smear layer is completely removed and the dental tubuli are, for the most part closed through inorganic melting if the Nd:YAG laser is applied with 15Hz/1.5W settings. ^[11] Similar results can be expected if the 810 nm laser diode is used. If the Er:YAG laser is applied, the smear layer will be completely removed and the dental tubuli remain open.

Disinfection Effect

GUTKNECHT et al ^[12] achieved an average of 99.92% bacterial reduction in the root canal using the Nd:YAG laser. In 1994, Rooney et al and Hardee et al

described reductions of 99 % when using a Nd: YAG laser in different experimental designs and bacterial combinations. Further studies examined the depth effect of the laser in the root canal dentine. In 1997, Klinke et al were able to prove a bactericidal effect of the Nd:YAG laser at a depth of 1,000 μm . In comparison, a rinsing solution, such as NaOCl, only achieves effective bacterial reduction up to a depth of 100 μm . Indications and contra-indications for laser supported endodontic treatments ^[13]

Laser-supported treatments should be favored when treating patients that show one or several of the following symptoms

- Teeth with a purulent pulpitis or pulp necrosis
- Teeth, of which the crown and root pulp show gangrenous changes
- Teeth with peri-apical lesions (peri-apical gap from 1 mm, up to granulomas with a diameter of 5 mm and more
- Teeth with a peri-apical abscess
- Teeth with lateral canals that lead to periodontal involvement
- Absorption of the apex caused by inflammation or trauma
- Teeth that have been treated for at least three months without success (with alternating rinsing and medicinal inlay).

Laser as a Diagnostic tool in endodontics-Determination of pulp vitality:

Laser doppler flowmetry is a device used to determine pulp vitality based on red blood cell flux in the pulp tissue. It is particularly useful for the detection of pulp vitality in traumatized and/or immature teeth (Singh et al., 2013).

Mechanism of Action

Light beams from the optical fibre enters the tissue, is absorbed to some extent by the blood cells and another fibre tip collects the scattered light and provides information about pulp vitality Its advantages are non-invasive, painless diagnosis of the tooth, reproducible, gold standard for pulpal blood flow determination. Limitations are- takes longer than other vitality determination techniques, requires a special device. Therefore, it is not conducted as a routine procedure in clinical practice.

Lasers in Pulp Capping ^[14]- for Indirect Pulpcapping

Pulsed Nd:YAG laser is used and black ink applied on the tooth surface. Air spray cooling is needed to prevent pulp damage resulting from the laser energy. CO₂ laser can also be used. In some cases, it is recommended that this laser be used with 38% silver ammonium solution. These treatments should be performed under local anaesthesia.

Direct pulp capping by laser ^[14]

CO₂ laser irradiation is performed at 1 or 2W after irrigating with 8% sodium hypochlorite and 3% hydrogen peroxide for more than 5 minutes. Calcium hydroxide paste must be used to dress the exposed pulp after laser treatment,

after which the cavity should be tightly sealed with cement such as polycarboxylate cement. Pulsed Nd: YAG, argon, semiconductor diode, and Er:YAG can also be used. Laser Ablation and Accessory

Treatment for Vital Pulp Amputation ^[14]

The lasers used are CO₂, pulsed Nd:YAG, He-Ne and low power semiconductor diode lasers and middle power semiconductor diode lasers. CO₂ laser usage is time consuming and pulp tissue may be damaged due to several exposures. Pulsed Nd: YAG causes damage to the pulp tissue and thereby showed a low success rate so it should be used only for pulp hemostasis, sedation, anti-inflammatory effects, and stimulation of remaining pulpal cells.

Laser & Dentin Hypersensitivity

The mechanism of laser for treatment of dentin hypersensitivity is not well explained, However Pashley suggests that it may occur through coagulation and protein precipitation of plasma in dentinal fluid or by alteration of nerve fiber activity. Laser therapy has been recommended by Kimura et al. to treat dentin hypersensitivity with effectiveness between 5.2% and 100%, depending on the type of laser and parameters used. According to authors, lasers are more effective than other treatments, although effect diminishes in severe dentin hypersensitivity. Mckarthy et al indicates that the reduction in dentin hypersensitivity could be the result of alteration of root dentin surface, physically occluding the dentinal tubules.

Laser in Analgesia

The pulsed Nd:YAG laser is widely used as an analgesia in endodontics. Its wavelengths interfere with the sodium pump mechanism, change cell membrane permeability, alter temporarily the endings of sensory neurons, and block depolarization of C and A fibers of the nerves.

Root canal disinfection and irrigation-The various uses of laser in root canal treatments are as follow

- Access cavity preparation and root canal orifice enlargement.
- Root canal wall preparation.
- Sweeping of Root canal and irrigation.
- Removal of pulp remnants and debris at the apical foramen.
- Sterilization or disinfection of infected canals.
- Obturation with gutta percha or resin.
- Removal of temporary cavity sealing materials, root canal sealing materials, and fractured instruments in root canals.
 - Access cavity preparation- Er,Cr:YSGG (2780nm) and Er:YAG (2940nm) can be used for access cavity preparation, root canal shaping and cleaning.
 - Root canal wall preparation-Lasers such as Er:YSGG (2780nm), Er:YAG(2940nm) and Nd:YAG(1064nm) are used for root canal wall

preparation [15]. When the laser fiber is unable to be inserted into the canals, reamers and files are to be used, followed by lasers. Smear layer is completely removed and dentinal tubuli are for the most part closed if pulsed Nd:YAG laser is applied at 15 Hz / 1.5 W settings.

- Sweeping of Root canal and irrigation are done in Straight, slightly curved and wide canals with lasers. Along with lasers, 5.25% Sodium hypochlorite or 14% EDTA must be used along laser irradiation. Nd:YAG are widely used for removal of pulp remnants and debris at the apical foramen. Removal of pulp remnants, control of hemorrhage, and stimulation of cells surrounding the root apex as well as debridement on the surface.
- Sterilization or disinfection of infected canals are done with Pulsed Nd:YAG, argon, semiconductor diode, CO₂, Er:YAG lasers. Because of laser energy and wavelength characteristic, they are useful in killing microorganism.
- In endodontics, lasers use the photo-thermal and photomechanical effects resulting from the interaction of different wavelengths and different parameters on the target tissues.

With vertical condensation method, obturation of canals can be done with Lasers. Anic and Matsumoto attempted to investigate whether it is possible to perform the root canal filling using sectioned gutta-percha segments and a pulsed Nd:YAG laser. With the lasers, Removal of temporary cavity sealing materials, root canal sealing materials, and fractured instruments in root canals became possible. [16] In fine and strongly curved canals, however, there were many cases in which laser tips perforated the canal wall.

Laser in Apicoectomy, Retrograde and Endodontic Apical Cavity Preparation, and Periapical Curettage

The advantages of laser application in endodontic surgery are identical to those that have been reported for other oral surgical procedures. Soft tissue lasers like the Nd:YAG; Diode or CO₂ can be used for providing clean incisions for gaining direct access to the peri radicular region. In addition, the use of lasers to replace aerosol-producing handpieces in periapical surgery can reduce the risk of contamination of the surgical environment by blood borne pathogens. The Er:YAG or the Er,Cr:YSGG lasers can be used for cutting into bone as well as sectioning the apical 3rd for apicoectomy & have also been researched for retro-preparation. The unique properties of laser light as they pertain to endodontic surgery are listed as follows: precision; coagulation; decreased postoperative pain, edema and reduced scarring; sterilization; selective absorption.

Vertical root fracture diagnosis and treatment

There are very few studies examining the use of lasers in diagnosing vertical root fracture cases. Although Kimura et al. (2009) used diagnodent for vertical root fracture detection in vivo, this technique appears to be impractical for clinical use. Vertical fractures can be treated using a surgical approach on the fracture side, which involves cleaning of the fracture line and filling with composite resin or bioactive materials. Thereafter, lasers can be used to accelerate soft tissue

repair, and this has been performed previously using low power laser therapy (Nogueira et al., 2012).

Laser Assisted Obturation

Due to their thermal effects clinicians have also tried using lasers like the Nd:YAG for thermosoftening gutta-percha; however there isn't much of an advantage seen over the thermoplasticised gutta-percha obturations systems commercially available today. Nd:YAG laser has also been used for sectioning excess gutta percha left after lateral compaction techniques.

Indication And Contraindication of Lasers In Endodontics Indications

- Teeth with lateral canal leading to periodontal involvement.
- Teeth with pulp necrosis and purulent pulpitis.
- Teeth with gangrenous changes.
- Teeth with periapical lesions up to 5mm or more.
- Teeth that have been treated atleast 3 months with no success.

Contraindications

- In advanced periodontitis cases.
- A deep crown and root fracture.
- Obliterated root canals in endodontic treated teeth

Conclusion

In today's dental treatment procedures lasers are playing very important role, if used efficaciously and ethically. As the advancement of much thin, elastic & long lasting fibres, application of lasers in root canal treatment is soon going to increase. Since laser technology came in the areas of dental treatment, the complicated techniques is becoming simpler with less consumption of time and hence improving ability to concern for patients. Due to relatively high-cost laser devices are have limited access. Evaluation of studies on laser showed that Nd:YAG laser treatment was effective in replacing the customary procedures.

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