

Lasers in Endodontic Therapy: A Review

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Abstract

The use of lasers for clinical reasons in the realm of dentistry has been viewed as a unique method. Numerous research has recently been carried out on the possible uses of laser therapy in endodontics. In addition, lasers have performed well for endodontic procedures such as root canal therapy, vital pulp therapy (pulp capping and pulpotomy), dentinal hypersensitivity treatment, and management of dental pain brought on by pulp and periradicular disease due to their ablation, penetrability, and disinfection capabilities. In this review, the advantages of laser-assisted pulp therapy are shown specifically through condensed clinical controlled trials and histology research. Furthermore, innovative deployment of lasers to hasten root development and remove foreign objects (such as broken files and fiber posts) from canals has swiftly become a cutting-edge trend in modern research. In this overview, the most recent research on all of the aforementioned laser applications is summarized and discussed.

Keywords: Dentinal hypersensitivity, Endodontic treatment, Laser therapy, Post-operative pain, Pulp capping, Pulpotomy, Root canal treatment.

INTRODUCTION

Several significant studies have attempted to discover and deploy novel technology to improve endodontic treatments throughout the last three decades. Endodontic treatment in dentistry entails removing bacterial contamination, cleaning the root canal system, and restoring the tooth's morphology and functionality.^[1] Among these investigations, studies on lasers of various wavelengths have proven crucial. Light Amplification by Stimulated Emission of Radiation (LASER) removes or treats soft and hard tissues in the oral cavity using amplified lights. Lasers are often classed based on their physical constructions and specific wavelengths, which have an impact on their improved clinical utilization. Lasers are classified into three types based on their physical construction.

The first type is a solid-state laser, so termed because the medium being vaporized is solid. The ruby laser is the prototype for all solid-state lasers: Crystalline materials doped with rare earth elements can be used to make a wide range of solid-state lasers. The YAG (Yttrium Aluminium Garnet) crystal (Holmium: YAG, Thulium: YAG, Neodymium: YAG, and Erbium: YAG) and the YSGG (Yttrium Scandium Gallium

Garnet) crystal (Er,Cr: YSGG) are two of the most common forms of solid-state lasers.^[1]

The gas lasers are the second most common type of laser. The ionized lasing material in this group can be argon gas, carbon dioxide gas, nickel gas, or a helium-neon (He: Ne) gas mixture. Diode lasers, which emit visible wavelengths, are the third class of lasers. The laser-amplified focused light energy has the potential to interact with biological dental tissues and structures to penetrate the tooth surface and gain access to the pulp cavity, clean, disinfect, and shape the root canal system, and eventually assist in three-dimensional filling. The most frequently used lasers in endodontics are: Neodymium: YAG (Nd: YAG), Diode Laser, Erbium: YAG (Er: YAG), Erbium Chromium: YSGG (Er,Cr: YSGG), and He: Ne laser. A position paper from the American Association of Endodontists states that the application

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of lasers to disinfect the root canal is more promising than in instrumentation and shaping of it.^[2]

MECHANISM OF LASERS

The primary and most important working principle of lasers is the direct use of laser irradiation on the electrical activity of nerve fibers occurring within the tooth pulp.^[3]

The second laser process modifies the dentin's tubular structure by melting or fusing a layer of hard tissue or smear, and then the dentinal tubules are sealed as a result.^[4]

Lasers take advantage of photothermal and photomechanical phenomena that happen when varied wavelengths and other parameters interact with the target tissue. Especially, the aggregation forms of germs, dentine, Smear layer, debris, and leftover pulp.^[5]

LASERS IN ROOT CANAL TREATMENT

Microorganism infection in the root canal systems is the main pathogenic cause for endodontic and periapical illnesses. The most popular and efficient procedure for preventing reinfection, enhancing periapical healing, and managing infection is root canal therapy, which involves shaping, cleaning, and filling the canals.

At present, rotary and manual devices are usually used for root canal shaping. The root canal walls should be free of the smear layer created during the treatment. Furthermore, bacteria that were present there will likely have an impact on the treatment's final efficacy.^[6]

It was discovered that laser irradiation could assist to form root canal walls and remove the smear layer once lasers were developed. The mechanism of lasers in the context of sculpting root canals is that laser irradiation can evaporate water in dental hard tissues and ablate the surrounding tissue, opening the dentinal tubules and removing the smear layer as a result.

In light of this, an *in vitro* investigation showed that when the space between the dentin and the tip was small, the Er: YAG laser could vaporize dental hard tissues, expose dentinal tubules, and remove the smear layer. In addition, the Er: YAG laser can lessen the possibility of dentine suture development, preventing root fractures.^[7]

LASER IN IRRIGATION

All this time, the cleaning and antiseptics of root canals – which is of key importance to a successful root canal treatment – primarily depends on two procedures, namely, mechanical instrumentation, and the disinfection of irrigates. However, when considering the fact that the anatomy of the root canal system is extraordinarily complicated, canal shaping performed with instrumentation is largely regarded as a means of creating access to the apical anatomy in the present.^[8]

Syringe and needle irrigation (SNI), still the most popular irrigation strategy in clinical settings, is used during traditional root canal therapy to remove debris and biofilms. SNI has some inevitabilities flaws while being practical and affordable, such being challenging to standardize and control and being less able to penetrate into uneven anatomical structures.^[9]

Many years ago, root canal irrigation was supplemented with laser-activated irrigation (LAI). The LAI mechanism creates tiny cavitation bubbles in irrigation solutions by the use of fiber tips. These bubbles' volumetric oscillation can lead to high-speed fluid motion, the formation of biofilms, and other contents in the root canals flowing vertically. The substances that are stuck to the root canal walls come off as a result of these repeated, swift movements, and are eventually flushed outside of the canals.^[10]

Photon-induced photoacoustic streaming (PIPS), a newly developed LAI technology, was first shown for clinical usage in 2012. It provides features of low energy (10 or 20 mJ) and short pulse length (50_s) as compared to standard LAI systems. By inserting its working tip in the crown side of root canals, this technique also has the capacity to prevent heat injury to the periapical tissue and root canal walls. Shock wave-enhanced emission photoacoustic streaming (SWEPS), which was developed to improve the PIPS method's debriding effectiveness.

SWEPS operates in a manner akin to extracorporeal shock wave lithotripsy. A second pulse is sent into the liquid as the cavitation bubble starts to deflate, creating a second cavitation bubble. The initial cavitation bubble then collapses violently as the second one speeds its deflation, creating a shock wave in the process. The debris connected to the walls is also removed by shock waves that are emitted by collapsing secondary cavitation bubbles that are near to the root canal walls.^[11]

PHOTO-ACTIVATED DISINFECTION (PAD) OF ROOT CANALS

Inadequate debridement and disinfection may lead to post-treatment endodontic disorders in the event that persistent germs are present within the root canal system. Different mechanical instrumentation techniques are insufficient for completely getting rid of the microorganisms inside the root canal system. To help reduce the microbial burden inside the root canal system, a variety of chemical irrigation solutions have been introduced. In addition, new technologies and materials have been suggested to enhance root canal decontamination, either by displacing current chemomechanical treatments or by enhancing their effects.

Using low-power lasers, such as a visible red diode laser with an output power of up to 100 mw, over the course of 60–120 s is the alternate method of micro-bial killing in the root canal system. To kill intracanal bacteria, including the resistant *Enterococcus faecalis* that is thought to be the primary cause of persistent apical periodontitis after root canal procedures, PAD drives photochemical reactions, particularly the production of

singlet oxygen, free radicals, and other reactive oxygen species from photosensitizer dyes like tolunium chloride. The laser energy should be administered using a photodynamic diffuser tip that produces a cylindrical emission pattern, matching the form of the root canal system, for maximal effect inside the root canal system.

The use of PAD in modern root canal procedures is related to its potential for one-step, high-level root canal space disinfection as a prerequisite to single-visit procedures, or as a remedy for resistant root canal infections. The low-level laser energy of PAD has benefits in that its bactericidal action could be performed without harming the host tissues and with little ocular threat to the user and patient.^[12]

LASER DOPPLER FLOWMETRY (LDF)

This method was initially created to measure blood flow in tiny vascular systems like the skin and retina. To monitor pulpal blood flow on human teeth, it was developed by Olgaret *et al.* in 1986.^[13] This diagnostic method was judged particularly suitable to determine pulpal vitality (blood flow) following tooth trauma when conventional clinical findings were ambiguous. In this method, moving blood cells scatter laser light, which then experiences a frequency shift in accordance with the Doppler principle. A signal that demonstrates the function of the red cell flux (volume of cells X cell velocity) is produced when the light is detected and processed.

It might be helpful in detecting revascularization considerably sooner than typical sensitivity tests in another modern application. Due to its cost, rarity, and skillful application in teeth with significant restorations, where the laser light might not reach the pulp and accurately monitor blood flow, LDF has various drawbacks.^[14]

TREATMENT OF DENTINAL HYPERSENSITIVITY

According to Brännström's hydrodynamic theory, dentine hypersensitivity happens when open dentinal tubules are exposed, causing a painful sensation since the dentinal permeability increases. Therefore, the goal of treatment should be to reduce this permeability, which can be done by destroying or blocking dentinal tubules.^[15] In 1935, Grossman listed seven original requirements for effective treatment of dentinal hypersensitivity using a variety of substances, including: non-irritating to pulp, relatively painless on application, easily applied, rapid in action, effective for a long time, without staining effects, and consistently effective. The effectiveness of the Nd: YAG and Er: YAG lasers in treating dentinal hypersensitivity has recently been compared in a number of studies.^[16]

According to Lan *et al.*, who used a morphologic research of the Nd: YAG laser to treat dentinal hypersensitivity, the dentine surface had no protruding rods after the laser treatment, in contrast to the presence of many rods before to laser irradiation. The data collected supported the idea that sealing exposed

dentinal tubules with Nd: YAG laser irradiation at specifications of 30 mJ, 10 pulses per second, and 2 min is possible when protrusive rods are a symptom of open dentinal tubules.^[16]

LASERS IN PULP CAPPING

The use of lasers in pulp capping has been studied clinically. A pilot study demonstrated that the hemostasis and decontamination steps of the diode 808 nm laser-assisted technique could improve pulp capping treatment results for carious exposure reasons.^[17]

A consensus was obtained in this regard through several histology experiments in animals. Following direct pulp capping with a low-level 980 nm laser application, the histology of pulpal and periapical tissue was examined. Mild inflammation, organized odontoblasts, thicker predentin in the pulp tissue, and greater fibrosis in the periapical region were all seen in the laser-assisted group. The histologic sections provided proof that direct pulp capping could improve healing when lasers were used.^[18]

On the other hand, there is some disagreement regarding how tissues react to lasers. According to Suzuki *et al.*, CO₂ laser irradiation can prevent dentin bridge formation by generating heat-denatured tissue around the exposed pulp. The severity of the thermally induced denaturation increased in direct proportion to the laser's power. The choice of the irradiation's wavelength or frequency was therefore thought to be significant.^[19]

In pulpotomy procedure, the dentist uses a spoon excavator to remove the putrescent coronal pulp after amputating it with a round bur at a slow speed. Moist cotton pellets containing ferric sulfate, formocresol, or other coagulative agents are added to the pulp chamber after it has been flushed and dried.^[20]

The use of lasers could assist in the operations by abrading the pulp to the canal level and facilitating the coagulation and healing of the pulp after full hemostasis.^[21] The use of lasers may have an impact on the clinical outcome of pulpotomy for primary teeth. Due to the laser's low noise and reduced contact between the tooth and mechanical instruments, which was especially appealing to pediatric dentists, it was introduced to address the challenges of managing the behavior of children undergoing dental procedures as well as the varying levels of cooperation.^[22]

LASERS IN PAIN MANAGEMENT

The prevention and management of pain during or after endodontic treatment are frequently crucial for the patient's comfort and quality of life as pain is a key issue for patients. Dental discomfort is frequently brought on by endodontic illnesses such acute apical abscess, irreversible pulpitis, and apical periodontitis.^[23]

Laser therapy has been shown to decrease the production of pain-inducing chemicals (such as substance P, histamine,

dopamine, and prostaglandins) while increasing the production of beta-endorphins, immunoglobulins, lymphokines, and anti-inflammatory prostaglandins. According to *in vivo* study, several laser-based treatments have the potential to significantly reduce pain by inhibiting neuronal activity, preventing conduction, disrupting fast axonal flow, and downregulating nociceptors' pain signals. Modern laser-based therapies (such as conventional laser use, photobiomodulation therapy, and antimicrobial photodynamic therapy) have been used to address pain relief in endodontics thanks to breakthroughs in laser technology.^[24]

Clinical trials have been conducted for a number of endodontic conditions. Patients with apical periodontitis typically experience spontaneous discomfort or pain on percussion when getting endodontic therapy. The degree of the accompanying pain may be lessened if the causes of infection and inflammation have been removed utilizing the proper methods. In addition, lasers with different wavelengths or application methods have been included in treatment modalities with the goal of cleansing and debriding the root canal system.

Yoo *et al.* used an intracanal irradiation technique to treat teeth with symptomatic apical periodontitis using a 1440 nm Nd: YAG laser. In the experimental group, the 300 m fiber optic tip was left dangling at the apical 3 mm level of the root canals for 10 s. They discovered that the irradiation group significantly outperformed the control group in terms of pain relief and the reduction of substance P, calcitonin gene-related peptide, and matrix metalloproteinase levels by combining the assessment of the patient's subjective pain level and the quantification of pain-related substances.^[25]

FUTURE DIRECTIONS

Laser technology is increasingly being used in dentistry as it develops. However, there are still a lot of unknown potential uses.

BROKEN FILES

There are two methods for removing separated instruments that have become stuck in the apical region: Either by directly irradiating the instrument with lasers to melt it, or by irradiating the dental tissue nearby with lasers to create a bypass that is then removed by other instruments. Both techniques, however, have non-negligible drawbacks, such as the fact that melting metal instruments requires high-energy lasers, which can cause thermal damage to the surrounding tissues; melting tissues around the instruments, on the other hand, does not require such high-energy but can easily result in lateral perforation when used for curved or thin-walled root canals.^[26]

FIBER POSTS REMOVAL

Clinically, mechanical or ultrasonic techniques are frequently used to remove glass fiber posts. However, these mechanical techniques can result in a clear loss of tooth structure, and the

heat produced during the procedure might harm the dental tissue as well. While ultrasonic techniques can lessen the loss of tooth structure compared to mechanical techniques, they can also create heat and microcracks, which raise the possibility of tooth fracture. Lasers have recently been employed to remove fiber posts. Deeb *et al.* discovered that the Er: YAG laser could successfully remove fiber posts when utilized with an endodontic tip in SWEEPS mode and a 2W, 15 Hz, 135 mJ, 50_s Er: YAG laser. Meanwhile, they found that the temperature rises and microcracks caused by lasers were less than those caused by ultrasonic instruments.^[27]

CONCLUSION

Lasers excite atoms or molecules to emit and amplify light of a given wavelength, resulting in coherent, monochromatic, well-controlled, and accurately directed light beams. These qualities make them helpful in a variety of disciplines, including transmission, imaging, and measuring. When a laser interacts with biological tissues, it creates unique biological effects such as thermal, photochemical, electromagnetic, and biological stimulating effects, which are the foundation of its medical applications. The rapid advancement of laser technology may usher in a new era of illness diagnosis, prevention, and treatment.

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