Journal of Dentistry Research

ISSN 2688-5549

Review Article

Clinical Applications of Lasers in Endodontic

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Abstract

The use of laser is becoming popular in the field of dentistry. The applications of lasers have improved the prognosis and outcome of dental treatments which is well documented in various literatures in general dentistry. Laser technology was introduced to endodontics in order to improve the results obtained from traditional procedures by increasing cleaning ability and the removal of debris with the smear layer from the root canal system, as the primary goal of endodontic treatment is to achieve optimum disinfection of root canal system. Various methods have been described in literature for improving the decontamination of root canal system such as chemical irrigation, mechanical cleaning and use of ultrasonic system. Nowadays, laser in endodontic has made revolutionary impact, it is primarily used for disinfecting root canal with better results and possible to penetrate in those complex areas of root canal such as lateral canal, which are very difficult to clean. The purpose of this article is to provide an overview of the current and possible future clinical applications of lasers in endodontics, including their use in alleviating dentinal hypersensitivity, modification of the dentin structure, pulp diagnosis, pulp capping and pulpotomy, cleaning and shaping of the root canal system, and endodontic surgery. Endodontic procedures for which conventional treatments cannot provide comparable results or less effective are emphasized.

Keywords: Endodontics; Laser; Apicoectomy; Ultrasonic; Pulp diagnosis

Introduction

The goals of endodontic treatment are to eliminate microorganisms from the root canal system, to remove pulp tissue that may support microbial growth, and to avoid forcing debris beyond the apical foramen which may sustain inflammation [1-3]. There are limitations of endodontic therapy such as lateral canals with various morphologies and dimensions [4,5], anatomical complexity, the difficulty of common irrigants to penetrate into the lateral canals and the apical ramifications. New materials, techniques and technologies are invented to improve the cleaning and decontamination of these anatomical areas. Laser technology was introduced to endodontics with the goal of improving the results obtained with traditional procedures through the use of light energy by increasing cleaning ability. The removal of debris and the smear layer from the root canals as improving the decontamination of the endodontic system.

History of lasers in dentistry

Newton described light in 1704 as a stream of particles. Maxwell's Electromagnetic (EM) theory in 1880, explained light as a rapid vibrations of EM fields due to the oscillation of charged particles. In 1917, the theory of stimulated emission was introduced by Albert Einstein, which is the principle the laser based on, when a photon interacts with an excited molecule or atom causes the emission of a second photon have the same frequency, polarization, phase and direction [6]. The acronym LASER stands for (light Amplification by stimulated emission). In 1958 Charles Townes and Arthur Schawlow "maser", acronym of microwave stimulated emission of radiation) [7-10]. The first application of a ruby laser *in vivo* was by the physicist Leon Goldman in 1965. He used it in dental tissues of his brother Bernard, who was a dentist, and however no success was achieved due to excessive thermal damage [11-14].

Citation: Abdo S, Alkaisi A, Saleem M, Zetouni J. Clinical Applications of Lasers in Endodontic. J Dent Res. 2018; 1(1): 1003.

Publisher Name: Medtext Publications LLC

Manuscript compiled: December 31st, 2018

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History of laser in endodontic

In 1971, lasers in endodontic were first documented by Weichman and Johnson [15], who used CO_2 laser to seal the apical foramen *in vitro,* and their goal was not achieved, in the same year Weichman and Johnson [15] attempts to seal the apical foramen by Nd:YAG laser, so more information was obtained regarding this laser's interaction with dentine. However the use of laser in endodontics was not feasible at that time. Er:YAG laser was approved by FDA in 1997, as the first dental hard tissue laser and the Er, Cr:YSGG, after one year [3], this has increased the use of lasers in clinics greatly.

Classification of lasers

Lasers can be calcified according its spectrum of light, clinical applications and active light medium (Table 1-3).

Mechanism of Action

Laser is created when the electrons in atoms in special glasses, crystals, or gases absorb energy from an electrical current or another laser become "excited". The excited electrons move from a lower-energy orbit to a higher-energy orbit around the atom's nucleus. When they return to their normal or "ground" state, the electrons emit photons (particles of light).

Table 1: Classification of lasers according to their wavelength position on the electromagnetic spectrum of light.

Ultraviolet	Visible	Near infrared	Medium infrared	Far infrared
Excimer 308 nm	Diode 445 nm (Blue)	Diode 810 nm	Er,Cr:YSGG 2,780 nm	CO_2 9,300 nm
	Argon 470 nm-488 nm (Blue)			
	Argon 514 nm (Green)	Diode 940 nm	Er:YAG 2,940 nm	CO_2 9,600 nm
	KTP 532 nm (Green)	Diode 970 nm		CO_2 10,600 nm
	Diode 635 nm-675 nm (Red)	Diode 1,064 nm		
		Nd:YAG 1,064 nm		
		Nd:YAP 1,340 nm		

Table 2: Calcification of laser dental lasers according to clinical applications.

Soft tissue lasers	Hard and soft tissue lasers	LLLT	Diagnosis
Diodes445 nm >1,064 nm	Er,Cr:YSGG, Er:YAG	Diodes 445 nm >1,064 nm	405 nm 655 nm
Nd:YAG, Nd:YAP	CO_2 9,300 nm		

Table 3: Calcification of laser based on active light medium.

Solid-state laser	Gas laser	Liquid laser	Semiconductor laser	Excimer
Nd:YAG	Argon	Dyes	Hybrid Silicon	Argon Florid
Diode	Carbon dioxide			Krypton florid
Er:YAG				Xenon Florid

These photons are all at the same wavelength and “coherent”, meaning the crests and troughs of the light waves are all in lockstep. In contrast, ordinary visible light comprises multiple wavelengths not coherent.

Laser light differ from the normal light, firstly, its light contains only one wavelength (one specific color), the particular wavelength of light is determined by the amount of energy released when the excited electron drops to a lower orbit, secondly, laser light is directional, whereas a laser generates a very tight beam, a flashlight produces light that is diffuse. Laser light is coherent; it stays focused for vast distances, even to the moon and back [3].

Applications of Lasers in Endodontics

Lasers in endodontics can be used for different purposes [16].

1. Alleviating dentinal hypersensitivity.
2. Modification of the dentin structure.
3. Pulp diagnosis.
4. Pulp capping and pulpotomy.
5. Cleaning and shaping of the root canal system.
6. Endodontic surgery.
7. Endodontic procedures for which conventional treatments cannot provide comparable results or are less effective such as:

Pulp diagnosis

Tenland in 1982 developed a Laser Doppler Flowmetry (LDF) and Hollway in 1983, to assess blood flow in micro vascular systems [17] and diagnosis of blood flow in the dental pulp [18], helium-neon and diode lasers at a low power of 1 MW or 2 MW is used in this technique [19]. The laser beam is directed to the blood vessels within the pulp through the crown of the tooth, when red blood cells moves causes the frequency of the laser beam to be doppler shifted and some of the light will be back scattered out of the tooth [18]. The reflected light is detected by a photocell on the tooth surface and its output is proportional to the number and velocity of the blood cells [20,21]. The main advantage of this technique over the electric pulp testing and other vitality tests, it is independent upon the occurrence of a painful sensation in determining the vitality of a tooth. LDF has a great value in reflecting the changes in pulp status after a horizontal root fracture [22], moreover, teeth that have a recent trauma or located in a part of the jaw that may be affected following orthognathic surgery, blood supply may be intact and pulp vitality are maintained, while the sensibility can be lost [18]. Following Le Fort I operations, it was reported that 21% of teeth in patients who did not respond to electrical stimulation, an intact blood supply was seen when tested with Laser Doppler Flowmetry [23]. LDF is reproducible and has become well-recognized as the gold standard for determination particularly for the detection of pulp vitality in traumatized and/or immature teeth [24,25]. However, it takes longer than other vitality determination techniques, and requires a special device; therefore, it is not used as a routine procedure in clinical practice. Laser Doppler Flowmetry has some limitations, it may be difficult to obtain laser reflection from certain teeth, generally, the anterior teeth have thin enamel and dentin, do not present a problem. Molars have thicker enamel and dentin with the variability in the position of the pulp within the tooth, may cause variations in pulpal blood flow [17,19]. Furthermore, differences in sensor output and inadequate calibration by the manufacturer may dictate the use of multiple probes for accurate assessment [26]. Laser Doppler Flowmetry assures an objective measurement of pulpal vitality, if the equipment costs decrease and clinical application improves, this technology could be used for patients with difficulties in communicating and young children whose responses may not be reliable [18].

Pulp capping and pulpotomy

Vital pulp therapy (pulpotomy) procedures using a LASER result in a bloodless field by vaporization, coagulation and sealing smaller blood vessels with a sterile wound. Melcer et al. [27] used CO_2 laser on beagle dogs and monkeys to achieve hemostasis after pulp tissue exposure, while other study compared the use of CO_2 laser for direct pulp capping with calcium hydroxide, after 12 months, the results showed, 89% success with laser and 68% with calcium hydroxide [28].

Nair et al. [29] used CO_2 laser in 5 teeth, after 7 days, none of 5 teeth showed any pathologic changes at pulp-dentin complex, while after 3 months post-operative 2 teeth showed subtle, yet, distinct apposition of tertiary dentin. One specimen showed mild inflammatory change with chronic inflammatory cells which was due to antigens or micro-leakage rather than laser therapy. One study compared clinical, radiographic, and histopathologic effects of pulpotomy using

Nd:YAG laser to formocresol one for 12 months follow up, the results showed that laser group had a clinical success rate of 85.71%, and radiographic success rate of 71.42% and formocresol group showed 90.47% success rate both clinically and radiographically [30]. Pulp capping is recommended when the exposure is very small, 1.0 mm or less and the patient is young; pulpotomy is recommended when the young pulp already is exposed to caries and the roots are not yet fully formed (open apices) [31,32]. The traditionally used pulp-capping material is calcium hydroxide [33-35], when it is applied to the pulp tissue, a necrotic layer is produced and a dentine bridge is formed. A recently introduced material, Mineral Trioxide Aggregate (MTA), shows a favorable results when applied to exposed pulp, it produces more dentinal bridging in a shorter period of time, with significantly less inflammation; however, 3 hours to 4 hours are necessary for its complete setting [36-39]. The success rate of direct or indirect pulp capping, ranges is 44% to 97%. In pulpotomy, the same agents are used until root formation has been completed, Nd:YAG and 9,600 nm CO_2 lasers can be used for this purpose, the 9,600 nm CO_2 laser energy is well absorbed by the hydroxyapatite of enamel and dentin, causing tissue ablation, melting, and solidification [40]. The use of 9,600 nm CO_2 laser did not cause any noticeable damage to the pulpal tissue in dogs [41]. Pulsed Nd:YAG laser with an energy below 1 W, a 10-Hz repetition rate, and an overall 10-second exposure time did not significantly elevate the intra pulpal temperature [42], this parameters may be considered safety parameters because the remaining dentinal thickness in cavity preparations cannot be measured *in vivo*, therefore it is recommended that clinicians choose laser parameters lower than these safety limits.

Laser ablation and accessory treatment for vital pulp Amputation [41], the lasers used are CO_2, pulsed Nd:YAG, He-Ne and low power semiconductor diode lasers and middle power semiconductor diode lasers. Using CO_2 laser is time consuming and may damage pulp tissue due to several exposures. Pulsed Nd:YAG causes damage to the pulp tissue and thereby showed a low success rates so it should be used only for pulp hemostasis, sedation, anti inflammatory effects, and stimulation of remaining pulpal cells [42].

Access cavity preparation

Laser has been used widely in root canal treatment starting from initial step to the last procedure of root canal [19]. Access cavity preparation, root canal shaping and cleaning can be done using Er,Cr:YSGG (2,780 nm) and Er:YAG (2,940 nm) lasers, for root canal wall preparation, Nd:YAG (1,064 nm) are used also to remove pulp remnants and debris at the apical foramen as well as control of hemorrhage [43]. Pulsed Nd:YAG laser is used at 15 Hz/1.5 W, can be eradicate smear layer completely with dentinal tubules sealing [44].

Root canal disinfection and irrigation

In dentistry various laser systems are used, the emitted energy can be delivered into the root canal system by a thin optical fiber (Nd:YAG, erbium, chromium: yttrium-scandium-gallium-garnet [Er,Cr:YSGG], argon, and diode) or by a hollow tube (CO_2 and Er:YAG). Thus, following biomechanical instrumentation, the potential bactericidal effect of laser irradiation can be used effectively for additional cleansing of the root canal system, this effect was studied extensively using different lasers as CO_2 [45,46], Nd:YAG [47-50], excimer [51,52], diode [53], and Er:YAG [54-57].

The Laser irradiation emitted from laser systems used in dentistry has the potential to kill microorganisms, their effect is directly related to the amount of irradiation and to its energy level [54]. It has been reported in several studies that CO_2 [57], Nd:YAG [58,59], argon [60], Er,Cr:YSGG [61], and Er:YAG [62,63]. Following biomechanical instrumentation, laser irradiation has the ability to remove debris and the smear layer from the root canal walls, disinfection of root canals by laser is well documented [64-66]. Diode lasers 980 nm could reduce *E. faecalis* up to 97% from infected bovine dentin disks [67], similar results were obtained using Nd:YAG lasers on dentin surfaces infected with Candida species [68].

Antimicrobial Photodynamic Therapy (APDT) is a two-step procedure, involves the application of a photosensitizer, followed by light illumination of the sensitized tissues, which will generate a toxic photochemistry on target cells that kill the microorganisms [68-70]. Nowadays, APDT is considered as a supplement to traditional protocols for canal disinfection and may be combined with the usual mechanical instrumentation and chemical antimicrobials [71,72].

Recently researchers have developed a novel formulation of photosensitizers in an approach to adapt and improve the antimicrobial efficacy of APDT in endodontics that display effective penetration into dentinal tubules, anatomical complexities, and anti bio-film properties. Well-designed clinical studies are currently warranted to examine the prospects for APDT in root canal disinfection [70,73].

Garcez et al. [74], compared the effectiveness of APDT, standard root canal therapy and the combined treatment to eliminate bacteria present in infected canals, the result showed that root canal therapy alone reduced bacteria by 90%, APDT alone reduced it by 95% and the combination of the two procedures reduced it by >98% [75]. Previously they had evaluated the antimicrobial effect of APDT combined with root canal therapy in necrotic pulps infected with microflora resistant to a previous antibiotic therapy, they concluded that endodontic treatment alone produced a significant decrease in numbers of microbial species, whereas the combination of endodontic treatment with APDT eliminated all drug-resistant species and surprisingly all teeth were bacteria-free. Also Garcez et al. [76] found that APDT applied with optical fiber is better than direct at the access of the cavity in root canal therapy infected with *Enterococcus faecalis*.

A comparison of the antimicrobial efficacy of 2 high-power lasers (Er:YAG and Nd:YAG) and 2 APDT systems with that of NaOCl action on *E. faecalis* was done, NaOCl was the most effective in *E. faecalis* elimination, Er:YAG laser resulted in great decrease in viable counts and the use of both commercial APDT systems resulted in a weak reduction in the number of bacteria [77].

Photo-Activated Disinfection (PAD) is another laser-activated disinfection technique requiring a photosensitizing dye and a specific wavelength, this combination has the ability to kill bacteria in planktonic suspensions and causes bacterial membrane distribution by releasing free radicals or reactive oxygen species [78,79].

PAD technique, high power diode lasers was compared with sonic activated irrigation and conventional irrigation to remove *E. faecalis* from straight root canals, PAD and sonic activated irrigation had better effects than the other techniques [80].

Despite the efficacy of lasers in disinfection, their use in direct contact with root canal walls may result in the side effects mentioned but PAD techniques have a lower risk of causing root canal wall deformation as they use low power lasers. However, it involves an additional step of dyeing the root canal wall and the laser light is only effective on stained root canal.

Photodynamic Therapy (PDT) using Toluidine Blue O (TBO) and a low-energy Light-Emitting Diode (LED) lamp has the potential to be used as an adjunctive antimicrobial procedure in conventional endodontic therapy [81].

Er-YAG lasers can activate irrigants and have a cavitational effect on them [82], although Deleu et al. [83] found that there are no significant differences between lasers activated irrigation and ultrasonically activated irrigation, several other studies have reported that the former produced better results than the latter [84-86].

In a study it was emphasized the possible limitations of using lasers in the root canal system and they suggested that "removal of smear layer and debris by laser is possible, however it is difficult to clean all root canal walls, because the laser is emitted straight ahead, making it almost impossible to irradiate the lateral canal walls". These investigators strongly recommended improving the endodontic tip to enable irradiation of all areas of the root canal walls [19] and was proved by a study which mentioned that when laser such as Nd:YAG in combination with mechanical enlargement and saline irrigation failed to eradicate black-pigmented bacteria intervention [87].

Although Laser activated irrigation has good results, however the main disadvantage is apical extrusion of the irrigation solution [88]; therefore in 2010 another design of the erbium laser tip was introduced, the so called PIPS-tip, which stands for "Photon-Initiated Photoacoustic Streaming" [70,89].

This method involves the introduction of a special tapered radial firing fiber tip through the root canal orifice, instead of being inserted into root canal. Pulsed laser operation induces photoacoustic shockwaves in the irrigant which travel throughout the RC system and allow their 3D movement. Using low, sub-ablative pulse energies (only 10 mJ or 20 mJ) the PIPS technique minimizes undesirable thermal effects on the dentinal walls seen with other methodologies. The use of very short (50 microseconds) laser pulses results-even with low pulse energies-in high peak powers, enables this powerful physical phenomenon, resulting in increased debris and smear layer removal with minimal or no thermal damage to the organic dentinal structure [89].

It has been found that the PIPS system had superior effects compared to the sonic and ultrasonic systems when used for calcium hydroxide and debris removal [90], while Deleu et al. [83] did not observe any differences between the PIPS technique and ultrasonically activated irrigation [91]. There are several limitations that may be associated with the intracanal use of lasers that cannot be overlooked [92], the emission of laser energy from the tip of the optical fiber or the laser guide is directed along the root canal and not necessary laterally to the root canal walls [93], thus, it is almost impossible to obtain uniform coverage of the canal surface using a laser with the ability to produce thermal damage to the periapical tissues [94].

PIPS technique had been evaluated *in vitro* both in EDTA and in NaOCl, the results showed a three-dimensional reduction of the bacterial load and its associated biofilm in the root canal system [95,96]. Conical tips were compared with flat tips they found that the optodynamic energy conversion efficiency of conical tips is three times higher than flat tips also a comparison between the PIPS tips 400/14 & 600/9 *vs.* the XPulse tips 400/14 & 600/14 showed that the tips (PIPS *vs.* XPulse and with the same fiber diameter) demonstrated comparable results for debris removal out of the root canal wall groove model with the tips at the level of the orifice and when pulse energy was kept identical for the fiber diameter (20 mJ or 40 mJ) respecting a pulse time of 50 microseconds and the setting at 40 mJ performed better than at 20 mJ; however care should be taken with the 40 mJ energy [97].

Today, there are two approaches endodontic fibers used in root canal cleaning and disinfection, the first approach is to use the fiber in a dried root canal, due to the straight forward laser beam, a spiral motion with the fiber is required in order to expose the root canal wall, removal of debris, smear layer and interaction with the biofilm is possible, as the effect of lasers is predominantly based on photo-thermal interaction [97].

The second approach is the use of the fiber in the irrigant itself, this can be done in the root canal or in the pulp chamber at the level of the orifice, the aim is to create cavitation or liquid motion (Laser-Activated Irrigation/LAI). Cavitation is based on the creation of vapor bubbles; liquid agitation is possible thanks to expanding and imploding bubbles. With this technology it is possible to use low energy and short activation times. The combination results in the creation of high peak powers, result in the agitation of the liquid without risk of thermal damage [97].

Unlike the conventional laser applications, the unique tapered PIPS tip is not mandatory to be placed inside the canal itself but rather in the pulp chamber only. This can reduce the need for using larger instruments to create larger canals so that irrigation solutions used during treatment can effectively reach to the apical part of the canal, canal ramifications, remove both vital and non-vital tissues, kill bacteria, and disinfect dentin tubules [90,93].

However, PIPS cannot completely remove bacteria from infected tubules but may remove biofilm better than passive ultrasonic irrigation [93]. It has been concluded that combinations of 20 s irradiation with Er:YAG laser *via* PIPS and 6% NaOCl has great effect in inhibiting *E. faecalis*. It is also showed 83% disinfection of the conventional needle irrigation after 20 min of continuous irrigation *vs.*100% disinfection on PIPS, with a total of 1 min of irrigation with the same solution [96]. While the combination of PIPS+6% NaOCl is more effective than water+PIPS or just irrigation with 6% NaOCl [93].

The effect of PIPS was evaluated using 6% NaOCl to remove an *in vitro* biofilm; the result showed an improvement in cleaning of the infected dentin on PIPS groups when compared to the Passive Ultrasonic Irrigation (PUI) group. The extraordinary result from this study was the fact that PIPS tip placed 22 mm away from the target area, while sonic, ultrasonic, and passive irrigation were made at the exact target area [98].

In an *in vitro* study, comparing the antibacterial effect of PIPS *vs.* a conventional irrigation, it revealed that there is no significant difference in reduction of colony-forming units and no bacteria could be observed by scanning electron microscopy in NaOCl, NaOCl+EDTA, and PIPS+NaOCl groups [73]. PIPS can increase the effect of irrigants commonly used in endodontic treatment such as NaOCl [99], while Er:YAG laser enhanced the smear layer removal ability of QMix in the apical thirds of the canals, QMix removed more smear layer in the coronal thirds when activated with the PIPS technique [100].

Sealing with or removal of Gutta Percha Obturation material

A number of studies have been carried out to establish the usefulness of lasers in the softening and obturation of gutta percha in the root canal [101-105], however, the development of thermoplastic materials and instruments for such purposes has regarded such application comparatively time consuming and expensive.

Root canal obturation involves 3-dimensional sealing of the root canal system with prevention of leakage from the apical foramen up to the coronal aspect of treated teeth. Complete sealing of the root canal may increase the clinical success to a rate as high as 96.5%.

A study compared the apical leakage of lateral condensation, gutta-percha softened by the Nd:YAG laser, and System-B technique, no significant difference was found in apical micro leakage among the 3 groups, however, lateral condensation and System-B resulted in less leakage than laser-softened gutta-percha [104]. While other study, concluded that Er:YAG laser irradiation (170 mJ to 250 mJ, 2 Hz) of the root canal did not affect apical leakage following obturation when compared with conventional methods [105]. They demonstrated that the use of the Nd:YAG laser was useful for the reduction of apical leakage and the application of Er:YAG laser beam (200 mJ, 4 Hz) for 60 seconds enhanced the adhesion of epoxy resin-based sealers in comparison with zinc oxide-eugenol-based sealers with increasing the frequency of the lasers, independent on power settings, resulted in increased adhesion of the sealer [106].

Root Canal System after Er,Cr:YSGG laser treatment enhance for Cleaning, Shaping, and Obturation of the Root Canal System greater number of canals/isthmuses [107].

The effects of Nd:YAG and diode laser irradiation on apical sealing when applied prior to filling the root canal with 2 different resin-based cements (AH Plus and EndoREZ) [108], leakage results as seen in SEM analysis.

The rationale for using lasers in nonsurgical retreatment may be attributed to their efficacy in removing gutta-percha and sealer from the root canal space [109]. The Nd:YAG laser at 3 output powers (1 W, 2 W, 3 W), enabled the removal of filling material in more than 70% of cases, and broken instruments in 55% of cases [109].

Pulsed Nd:YAG laser was used in removing 2 types of endodontic obturation materials from the root canal *in vitro*, results showed that although none of the methods used in this study resulted in complete removal of debris from the root canal wall, the time required for the removal of any of the root canal obturation materials using laser ablation was significantly shorter than that required using the conventional method [101,110], they concluded that Nd:YAG laser irradiation is an effective tool for the removal of root canal obturation materials, and may offer advantages over the conventional method [101,110]. While the Nd:YAP laser could not completely remove debris and obturating material from the root canal space [111].

After conventional retreatment flares up or post-operative pain may develop, using Low-Level Laser Therapy (LLLT) reduces postoperative pain after root canal retreatment of mandibular molars, it is a practical, non-pharmacologic technique for reducing pain [112].

Laser in apicoectomy, retrograde and endodontic apical cavity preparation, and periapical curettage

Laser for endodontic surgery are the same as those that have been reported for other oral surgical procedures, soft tissue lasers such as Nd:YAG; Diode or CO_2 can be used to provide clean incision for gaining direct access to the periradicular region. Additionally the advantage of lasers is to replace aerosol-producing hand pieces in periapical surgery which can reduce the risk of contamination of the surgical environment through blood borne pathogens [113].

The Er:YAG or the Er,Cr:YSGG lasers can be used to section the apical 3rd for apicoectomy and retro-preparation.

The unique properties of laser in endodontic surgery are: precision; sterilization; selective absorption, coagulation, edema and reduced scarring; fasten the healing of wound, providing relatively bloodless, reduces the amount of bacteria and other oral pathogens in the surgical field, less pain , and provide good hemostasis with reduced need for sutures [112,113]. Periapical lesions of sinus tract can be treated with Pulsed Nd:YAG and CO_2 lasers; however an *in vivo* study was conducted on apical surgery of dogs using CO_2 laser, the success rate did not improve following surgery despite its potential to lower dentin permeability [114].

Another prospective study of two apical preparations for retrogrades endodontic with and without CO_2 laser, 320 cases were evaluated, and the results did not show improvement of the healing process by CO_2 laser [115]. While *in vitro* studies [116-119] using the Nd:YAG laser result in reduction in the penetration of dye or bacteria through resected roots, they suggested that the reduced permeability in the lased specimens probably was due to the changes in dentin structure following laser application [110]. Although SEM examination showed melting, solidification, and recrystallization of the hard tissue, the structural changes were not uniform and the melted areas appeared connected by areas that looked like those in the non lased specimens, that is why the permeability of the dentin was reduced but not completely prevented, it is reasonable to assume that homogeneously glazed surfaces would be less permeable than partially glazed ones [120].

Rotundo et al. [121] compare dye penetration after retrograde cavity preparations of extracted teeth between Er:YAG and laser ultrasonic tools, the results showed no significant difference between the two groups, there was no any reduction in the dentin permeability after lasing with Er:YAG as it does not melt or seal the dentinal tubulmes, while Nd:YAG laser has been found to have the ability of reduction in permeability of resected roots [116].

When comparing connective tissue response over time to resected root segments with Nd:YAG laser-cut surfaces was delayed than with those resected with a bur-cut [122].

Numerous studies have shown a lower postoperative discomfort, even in periodontal therapies, in patients treated by Er:YAG lasers [123], however postoperative pain after endodontic surgery can be reduced by application of low level laser [124].

Cavity preparation using Er:YAG showed smooth clean surfaces, significant low micro leakage for all tested materials with no thermal damage signs, however Ho:YAG laser causes some thermal damage [125-127].

The main objective of endodontic surgery is apical seal, a study was conducted comparing the apical seals achieved by retrograde amalgam fillings and Nd:YAG laser, the results showed no statistically significant difference in bacterial leakage was found between the two groups [119]. Cracks on root end following resection and cavity preparation with a laser and other techniques has no effect on the number of cracks formed on surfaces [128] and laser treatment may produce more irregular surfaces comparing the bur [129].

To increase the successful rate of endodontic surgical procedures, an attempt using Nd:YAG laser may result in dentinal tubules sealing and bacterial reduction. Er:YAG laser resulted in no discomfort, less contamination of surgical site, and no smear layer. However, better healing achieved with Ga-Al-As laser.

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