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# SYNOPSIS ON THE ROLE OF DIODE LASER IN ROOT CANAL DISINFECTION

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**Abstract:** Effective root canal disinfection is necessary for success of endodontic treatment. Traditional chemo-mechanical techniques such as sodium hypochlorite, mechanical preparation and calcium hydroxide used for intracanal disinfection usually fail in cases of biofilm-related infections. Therefore, several new strategies are applied for root canal disinfection. One of these strategies is using of diode laser that has recently gained significant attention in the endodontic practice due to its antibacterial action, bio-stimulation, decrease of pain and improvement of success. Moreover, it has several advantages like its low cost, easily application, penetration power into dentine and smaller size device compared with other types of lasers. Diode laser has been applied for root canal disinfection with various degrees of success in both *in vitro* and *in vivo* studies. Nevertheless, small number of published randomized clinical trials in humans with small sample sizes and high heterogeneity provide insufficient support for its efficacy. Furthermore, the results of diode laser in root canal disinfection are controversial. Future high quality studies are recommended to assess the effectiveness of diode laser on various microbial endodontic species and to confirm its role in disinfection of the root canal system in human teeth. This synopsis describes the current scientific understanding and the status of diode laser efficacy in root canal disinfection.

**Keywords:** Apical periodontitis, *Enterococcus faecalis*, Necrotic pulp, Regenerative endodontic therapy, Root canal

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# SYNOPSIS SUR LE RÔLE DU LASER À DIODE DANS LA DÉSINFECTION DU CANAL RADICULAIRE

**Résumé:** Une désinfection efficace du canal radiculaire est nécessaire pour un bon succès du traitement endodontique. Les techniques chimio-mécaniques traditionnelles telles que l'hypochlorite de sodium, la préparation mécanique et l'hydroxyde de calcium utilisées pour la désinfection intracanalaire échouent généralement en cas d'infections liées au biofilm. Par conséquent, plusieurs nouvelles stratégies sont appliquées pour la désinfection des canaux radiculaires. L'une de ces stratégies est l'utilisation du laser à diode qui a récemment attiré une attention considérable dans la pratique endodontique en raison de son action antibactérienne, de sa biostimulation, de sa diminution de la douleur et de son haut taux de succès. De plus, le laser à diode présente plusieurs avantages tels que son faible coût, sa facilité d'application, son pouvoir de pénétration dans la dentine et son dispositif de plus petite taille par rapport aux autres types de lasers. Il a été appliqué pour la désinfection des canaux radiculaires avec divers degrés de succès dans des études in vitro et in vivo. Néanmoins, un petit nombre d'essais cliniques randomisés publiés chez l'homme avec des échantillons de petite taille et une forte hétérogénéité ne soutiennent pas suffisamment son efficacité. De plus, les résultats du laser à diode dans la désinfection canalaire sont controversés. De futures études de haute qualité sont recommandées pour évaluer l'efficacité du laser à diode sur diverses espèces endodontiques microbiennes et pour confirmer son rôle dans la désinfection du système canalaire des dents humaines. Cet article décrit les connaissances scientifiques actuelles et l'efficacité du laser à diode dans la désinfection canalaire.

**Mots clés :** Parodontite apicale, Enterococcus faecalis, Pulpe nécrotique, Thérapie endodontique régénérative, Canal radiculaire

## Introduction

A fundamental prerequisite for endodontic treatment is effective root canal disinfection. Traditionally, mechanical preparation, sodium hypochlorite irrigant, and calcium hydroxide have been recommended for root canal disinfection [1-5]. However, they are ineffectual in cases of biofilm-related chronic infection, therefore other intracanal drugs, such as triple antibiotic paste (TAP) and double antibiotic paste (DAP), are proposed as substitutes or adjuncts in root canal disinfection [6-8]. Moreover, some natural products like propolis, chitosan and Aloe vera have been applied for intracanal disinfection [9-13].

Although sodium hypochlorite is the gold standard for root canal disinfection [14-16], it has some drawbacks, including substantivity and smear layer removal ability [17]. Furthermore, chemical disinfection is dependent on the extent to which chemical agents penetrate the root canal system [18]. As a result, the search for an optimal new intracanal disinfectant is ongoing due to the current rise in antibiotic-resistant bacteria and negative effects caused by the chemicals utilized [19, 20].

Several research on the possible benefits of laser in endodontics have been published since the introduction of the ruby laser by Maiman in 1960 and the application of laser for endodontic therapy by Weichman in 1971 [21]. The use of laser in endodontics has expanded in recent years due to the development of thinner, more flexible, and durable laser fibers [22]. Lasers, such as diode lasers, can be sent into the root canal system via fiber optics or hollow tubes, like Er-YAG lasers. These various go delivery strategies can have an impact on the performance of similar lasers in canal disinfection [23].

Due to its antibacterial action, bio-stimulation, boosting success rate and lifespan, and exploiting the thermal effect of laser on surrounding tissues, the use of laser power has recently attracted significant interest in the endodontic profession [24, 25]. This may save patients from invasive surgical intervention, saving both the patient and the dentist time.

The interaction of laser light with tissues occurs in four ways: reflection, scattering, transmission, and absorption [26]. The wavelength of the laser, as well as the optical features of the target tissues such as pigmentation (chromophores) and water content, determine laser absorption. Melanin, hemoglobin, and water are the primary chromophores in intraoral soft tissue [27]. Water and hydroxyapatite are the primary chromophores in hard tissues. Because different wavelengths are required for different uses, different types of laser power are necessary in dental treatment [26, 27].

The laser wavelengths used for disinfecting the root canal include: erbium: yttrium aluminium garnet (Er:YAG), 2940 nm; erbium, chromium: yttrium scandium galium garnet (Er,Cr:YSGG), 2780 nm; neodimium: yttrium aluminium garnet (Nd:YAG), 1064 nm; diode, 635 to 980 nm; potassium titanyl phosphate (KTP), 532 nm and carbon dioxide ($CO_2$), 9600 and 10600 nm [28].

Diode laser is a solid-state semiconductor laser with wavelengths for dental applications ranging from 800 to 1,064nm. Because of their high absorption in pigments such as melanin and hemoglobin as well as transmission in water and hydroxyapatite, diode lasers are increasingly being used for root canal therapy. It promotes cell proliferation while inhibiting inflammation-causing enzymes. The efficacy of root canal disinfection utilizing diode laser wavelengths 940 nm and 980 nm was reported to have a good bactericidal impact on *Enterococcus faecalis* (*E. faecalis*) [29, 30].

Another important issue with endodontic treatment is the post-operative endodontic pain that many patients endure. When patients experience discomfort following endodontic treatment, they may mistrust the clinician's abilities. As a result, effective pain management is crucial and diode laser is able to inhibit the inflammation-inducing enzymes [31].

This synopsis describes the current scientific understanding and the status of diode laser efficacy in root canal disinfection.

**Antibacterial activity of diode laser**

Although several studies have been conducted to assess the role of diode laser in disinfection of the root canal system, the results of these studies are controversial. Some authors recommended using of diode laser as an adjunctive treatment to the chemo-mechanical methods [32-36]. On contrary, others concluded that diode laser, as a monotherapy, has a beneficial antibacterial action during root canal disinfection [37-40].

Several recent studies concluded that diode laser therapy has a limited effect on bacterial cell eradication and use of a laser as an adjuvant to regular sodium hypochlorite irrigation is a beneficial strategy [32-36]. Moreover, diode laser in continuous mode is more effective than both diode laser in pulse mode and 5.2% sodium hypochlorite solution [37].

Several studies have been concluded that diode laser can be used for complementary disinfection of root canals due to its antibacterial action. When diode laser treatment was used for root canal disinfection, a statistically significant reduction in microorganisms was observed [38-40].

The principles underlying a high-power diode laser's antibacterial properties are based on the thermal and photodisruptive effects of the produced light. High-energy radiation characterizes diode lasers with wavelengths of 980 nm. The energy is transformed to heat when it is absorbed by the water molecules in the tissues. As a result, water evaporation causes cell damage and microorganism mortality. However, there are additional published theories about bacterial cell death by laser light [41]. One plausible assumption is that following irradiation, the temperature rises to an exceedingly high level for a brief period of time, and the intense heat results in the instantaneous killing of the bacteria [41].

Another theory assumes that immediate cell death may not occur during laser irradiation, but sublethal damage. Sublethal damage is explained as a disruption of cell wall integrity and the accumulation of denaturated proteins. Those changes cease the cell growth and result in cell lysis [10]. This last assumption was also described by Moritz *et al*. [42]. They concluded that laser irradiation had a cumulative effect on *E. faecalis* lethality. Heat from laser application is a stress component that causes nonlethal reversible damage that may be changed into lethal damage once the stress is repeated [43].

Diode laser is applied in many investigations due to its efficacy in lowering intracanal bacterial counts and penetrating 500 microns into dentin, low cost and smaller size than other types of lasers [44]. Morsy *et al.* evaluated antibacterial effect of 980 nm diode laser versus conventional endodontic treatment in necrotic teeth with chronic periapical lesions. They concluded that diode laser has efficient antibacterial effect [25]. An *in vitro* study concluded that diode laser irradiation (970 nm) has efficient antibacterial effect in comparison to silver nanoparticles on *E. faecalis* bacterial strain [24]. Moreover, a statistically significant reduction in the number of intracanal *E. faecalis* colonies was observed following a single and repeated 980 nm diode laser application [45].

Similarly, when compared to NaOCl 5.25% solution, ER, Cr: YSGG laser 2780nm wavelength and diode laser 940nm wavelength show approximately identical antibacterial activity on *E. faecalis* [46]. Bago *et al.* found that using a diode laser (985 nm, 2 W, 3x20 s) against *E. faecalis* biofilm was comparable to using 2.5% NaOCl for 60 seconds [47].

Unfortunately, there haven't been enough randomized clinical trials evaluating endodontic treatment outcomes after laser use [28, 44]. Future high-quality studies are highly recommended on this topic.

**Effect of diode laser on the post-operative endodontic pain**

Endodontic disorders such as irreversible pulpitis, apical periodontitis, and acute apical abscess are among the most common causes of dental pain [48, 49]. Pre-operative and chronic pain is a significant risk factor for endodontic treatment failure [50]. Meanwhile, as a common complication following endodontic therapy, post-operative endodontic pain has been found to have a prevalence of up to 40%, and pain control has been identified as a critical aim of endodontic therapies [51].

Standard chemomechanical-preparation may pose an ongoing risk of inflammation and post-operative pain. All the while, diode laser may reach microbes in deeper dentin layers without causing damage to the tooth structure [52]. Lasers have been shown to decrease pain-inducing chemicals (such as substance P, histamine, dopamine, and prostaglandins) while increasing synthesis of lymphokines, immunoglobulins, anti-inflammatory prostaglandins, and beta-endorphins [53].

Mutiple studies have been carried out to study the effect of diode laser on pain after endodontic therapy [54-56]. All of these studies confirmed the beneficial role of diode laser in decreasing the pain after edndodontic treatment. According to the findings of Kaplan *et al.*, diode laser can reduce post-operative pain after endodontic therapy in teeth with apical periodontitis [30]. Moreover, Morsy *et al.* found that diode laser 980 nm induces efficient decrease in the post-operative pain versus conventional endodontic treatment in necrotic teeth with chronic periapical lesions [25].

**Effect of diode laser on biomodulation**

Photobiomodulation therapy through the application of photonic energy at specific wavelengths within the optical window of 650-1350 nm, works on the principle of inducing a biological response through energy transfer [57]. Cellular metabolism can be modulated, leading to secondary effects which modify cellular behavior. The benefits of this approach can be described as anti-inflammatory, analgesic and therapeutic and with a correct incident dose applied; photobiomodulation therapy has no appreciable thermal effects in irradiated tissue [58, 60]. *In vivo* studies have shown that photobiomodulation can inhibit nerve function. Other alterations include local conduction blockage that give rise to pain relief and are reversible without side effects [61].

A recent study compared the effect of low-level laser therapy on post-operative pain after single-visit root canal retreatment on mandibular molars. It concluded that low-level laser therapy reduces post-operative pain after single-visit root canal retreatment of mandibular molars only four hours following the procedure [62]. Using biostimulation technique as low-level laser treatment enhances regeneration processes without significantly elevating body temperature. Biostimulation accelerates cellular metabolism, protein expression, cell migration, proliferation, and differentiation [38, 63].

An *in vitro* study evaluated the effect of 970 nm diode laser potentiality on proliferation of dental pulp stem cells with fiber optic tip 320nm in continuous wave and noncontact mode. The authors concluded that the diode laser power enhances proliferation of dental pulp stem cells [63]. In another study, the efficacy of diode laser in maturogenesis of immature teeth with necrotic pulps was evaluated. The study concluded that the diode laser has efficient antibacterial effect and can be used instead of TAP [64].

Recently, effect of biostimulation on the regenerative response of immature teeth with necrotic pulp and apical periodontitis was assessed in dogs. The results revealed that using of biostimulation by seven sessions at 808 nm diode laser and output power of 300 mW for 90 seconds showed marked increase in root length, thickness and decrease in apical diameter. Furthermore, it showed significant higher score of vital tissue infiltration and low inflammatory scores than non-biostimulated group. The authors concluded that biostimulation enhances the response of immature teeth with necrotic pulp and apical periodontitis to regenerative endodontic therapy (RET) improving root maturation [65]. Similarly, diode laser 980 nm can alternate DAP as a disinfection method of the root canal during RET for mature necrotic teeth [39]. Therefore diode laser can accelerate RET for both the patient and dentist in a single visit.

**Limitations of diode laser in root canal disinfection**

Power density, irradiation frequency, wavelength, cycle duration, and dentine thickness all have a direct impact on the photothermal effect of high power laser light [66]. Proper laser parameter selection not only has a therapeutic impact, but also aids in the prevention of damage to periodontal ligament cells and alveolar bone. The photothermal effect, which generates a temperature increase of 10°C for more than one minute, has the potential to cause irreversible changes to the root dentine and surrounding tissues [67].

Several constraints must be considered while using lasers inside the root canal. To begin, laser light with a divergence angle of only 18 to 20 degrees is emitted in a straight line from the tip of an optical plain-ended fiber or a laser guide [68]. With such a unidirectional laser beam, it is difficult to achieve uniform irradiation of the whole root canal dentine surface [68, 69]. Furthermore, root canal preparation and retreatment with laser and plain fibers are risky in curved root canals due to the potential of generating ledges and holes [70, 71]. When irradiating root canal dentine, a helicoidal withdrawal motion from apical to coronal section is proposed to increase the surface area [72].

To ensure that the laser covered the whole interior wall of the canal, the laser fiber is moved in a circular motion from the apex to the coronal end and back again. The internal canal wall is not touched with the fiber tip to avoid melting the dentin and extending the heat effect to the region of the periodontal ligaments [39]. In order to provide a powerful laser beam, the fiber tip was also kept clean [73].

Intracanal irradiation is typically done in a pulsed fashion to reduce the danger of thermal harm to the external root surface, periodontal tissues, or underlying bone, which reduces post-operative pain and improves periapical healing [31, 39, 74]. Furthermore, new conical side-firing fiber tips with 80% lateral and 20% forward radiation cover the whole intracanal wall [75].

Another constraint is the safe use of lasers in the root canal, particularly when utilizing erbium lasers at ablative settings. Lasers may cause thermal injury to periradicular tissues through the open apical foramen [76].

## Conclusion

When compared to other types of lasers, diode laser has various advantages such as efficient antibacterial activity, low cost, ease of administration, high penetration power into dentine, and a smaller size device. Nonetheless, a few numbers of human randomized clinical trials with small sample sizes and substantial heterogeneity give insufficient support for its efficacy. Future research should look at the antibacterial effects of diode laser on different microbial endodontic species, as well as the role of diode laser in root canal disinfection in human teeth.

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