Laser application in modern endodontic practice – Review

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Приложение на лазерите в съвременната ендодонтска практика Литературен обзор

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Summary

Introducing new devices and technologies for endodontic procedures has always been a challenge. Since the discovery of the Mayman red laser in 1960 and the use of the Weichman endodontic laser in 1971, a variety of potential uses for endodontic lasers have been proposed. During the last two decades, a lot of experience and knowledge has been accumulated, with different types of lasers - CO_2, Er: YAG, Er, Cr: YAG, Nd: YAG, KTP-Nd: YAG, Er: YSGG, argon and diodes, used in a number of endodontic procedures. Such procedures include pulp diagnostics (laser Doppler fluometry), biological treatment, pulpotomy, cleaning, disinfection and obturation of the root canal system, treatment of endodontically treated teeth and apical surgery.

Despite the wide range of applications in endodontics, lasers cannot replace conventional techniques and are still relatively expensive and have limited accessibility. Diode lasers are economically viable with reasonable price and long lifetime. They have the ability to combine different resonant frequencies and wavelengths, which encourages new studies in the field.

Keywords: *application, endodontics, lasers*

Резюме

Търсенето на нови устройства и технологии за ендодонтски процедури винаги е било предизвикателство. От откриването на червения лазер от Майман през 1960 г. и използването на лазера в ендодонтията от Weichman през 1971 г., са предложени разнообразие от потенциални възможности за употреба на лазерите в ендодонтията. През последните две десетилетия са натрупани много опит и знания, като различни видове лазери - CO_2, Er: YAG, Er, Cr: YAG, Nd: YAG, KTP-Nd: YAG, Er: YSGG, аргонов и диодни, се използват при редица ендодонтски процедури. Извършват се пулпна диагностика (лазерна доплерова флуометрия), биологично лечение, пулпотомия, почистване, дезинфекция и обтуриране на кореноканалната система, прелекуване на ендодонтски лекувани зъби и апикална хирургия.

Въпреки широкия спектър на приложение в ендодонтията, лазерите не могат да заместят конвенционалните техники, а и все още са сравнително скъпи и достъпът до тях е ограничен. Икономически изгодни – с достъпна цена и дълъг живот, възможност за комбиниране на различни резонансни честоти и дължини на вълната, са диодните лазери, което насърчава много нови изследвания.

Ключови думи: *ендодонтия, лазери, приложение*

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Introducing new devices and technologies for endodontic procedures has always been a challenge. Since the discovery of the Mayman red laser in 1960 and the introduction of the endodontic laser by Weichman in 1971, a variety of potential applications have been proposed for endodontic lasers [1, 2, 3, 4]. With the creation of thinner, more flexible and durable optical fibers, and increased knowledge of the biological effects of laser radiation, the use of lasers in endodontics has increased [5, 6, 7]. For the past two decades, a great deal of experience and knowledge has been gained in the use of lasers in endodontics [7].

In 2010 the American Dental Association described the numerous applications of endodontic lasers in pulpotomy, blood flow measurements, apicoectomy, opening of landmarks, and softening the gutta-percha. Lasers used as an adjunct have been shown to aid root canal dissection. *In vitro* studies have shown that lasers are equivalent to conventional rotary instruments for the coronary and middle thirds of the root canal system , but worse for the apical third [8].

Laser Doppler Fluometry. Laser blood flow measurement in the dental pulp is an accurate and non-invasive method that is an important diagnostic test for the condition of the microvascular system in the pulp. Infrared (780-820 nm) or near-infrared (632,8 nm) emission lasers, aimed at optical fiber fabric, are used. In contrast to electrododontodiagnosis, the subjective response of the patients is excluded here - it can be used in the treatment of adults as well as children, even in the first days after trauma [5, 6, 9, 10]. Laser Doppler fluometry has not yet been widely used in dental practice as it requires special equipment, licensed data processing software, and presents complexity and performance constraints [9, 11].

Biological treatment. The most recent literature reports indicate more predictable and better results with the use of lasers for biological treatment. Higher success rates (about 90%) have been reported using a laser with different wavelengths than traditional procedures (about 60%). Reducing the dentin permeability, achieved by restricting the dentin ducts, is crucial. A CO_2, Er: YAG and Er, Cr: YSGG laser can be used for this purpose, the latter showing the best results [5, 6, 12, 13]. The effect of the Nd: YAG laser is still being investigated due to conflicting data on the thermal effect on the dental pulp under different modes of operation [5, 6].

Pulpotomy. Recent advances in laser technology have made lasers more attractive in endodontic applications, where they can be used as an additional or alternative method to traditional pulpotomy. Laser treatment has advantages with respect to control of hemorrhage, sterilization, and stimulation effects on the dental pulp cells. Since the effects of ruby laser irradiation on dental pulp tissue were reported, other studies using $CO_{2,}$ Nd:YAG, Er:YAG, Er,Cr:YSGG, diode laser, and argon laser pulpotomies have been published. Diode lasers have been applied widely in oral surgery procedures involving soft tissue. Soft tissue surgery can be performed safely in close proximity to enamel, dentin, and cementum because these lasers are relatively poorly absorbed by the tooth structure. Diode lasers can be used for ablation, incision, and excision (cutting, vaporization, curettage, coagulation, and hemostasis). Furthermore, the laser has the advantages of being portable and compact with a minimum setup time. Based on these characteristics and previous studies, the lasers could be an alternative to pulpotomy therapy [15, 16, 17, 18].

Nd: YAG, CO_2 and diode lasers are used in laser pulpotomy and show better results than conventional methods. As in electrosurgery, Nd: YAG, CO_2 and diode lasers have a 100% success rate in controlling tooth pulp bleeding [15, 16, 17]. Laser emission properties include depth of penetration, power and impact time which make these lasers sufficient for photocoagulation of the blood vessels in the pulp [18].

In a clinical study of the impact of a Nd: YAG laser with a power of 20 W and a pulpotomy frequency of over 90%, the success rate of the control group with Formocresol was 69% [17].

Durmus et al. use high energy diode laser for coagulation of pupltomy with flexible optic fibre with diameter 400 μm at frequency - 30 Hz, energy - 50mJ, power - 0W to 1.5W for 10 seconds with air cooling. They conclude that laser pulptomy has high clinical success and 1.5W is an effective final power [18]. There are also positive clinical results using CO_2 laser in pulsed mode that stand a power of 3 W irradiating the pulp- the pulp is irradiated for 2.5 s with 0.8 mm ceramic nozzle [19].

The laser pulpotomy is more time-efficient allowing better cooperation with the patient and easier use [18].

Cleaning and disinfection of the root canal system. The task of cleaning and disinfecting the root canal system becomes more difficult with the increase in the virulence of the bacteria. This results from their increased pathogenic potential and the increased resistance of a biofilm to antimicrobial agents. Numerous studies have been conducted on the bactericidal effectiveness of laser irradiation with different types of laser systems - CO_2, Nd: YAG, Er, Cr: YAG, Er: YAG, argon and diode laser [2, 3, 5, 6, 7, 20]. Bergman et al. conclude that the application of Nd: YAG lasers is not an alternative but rather a possible addition to existing channel disinfection protocols, with laser light properties expressing a bactericidal effect at a dentin depth of more than 1 mm [21, 22, 23].

Laser irradiation with the correct parameters evaporates the smear layer and the organic structure of dentin (collagen fibers), which is characterized by a superficial fusion of the dentin tubules. Partial or approximately complete closure of the dentin tubules and melting of the intertubular dentin renders the dentin surface smooth with an excellent removal of the smear layer. In this way, dentin permeability is reduced [24], which in turn results in a significant reduction of the number of the bacteria in the root canal system. Similar results have been described by other authors who report the melting and recrystallization of restricted portions of root canal dentin [25, 26, 27].

The use of erbium lasers in root canal irrigation, in combination with different irrigators, has better self-irrigation results [28, 29, 30]. There is a consensus in the literature that laser radiation used in endodontics has the ability to destroy microorganisms and its effect is directly related to the amount of radiation and its energy level [5, 6].

The radiated energy can be transmitted to the root canal through thin optical fibers (Nd: YAG, KTP-Nd: YAG, Er: YSGG, argon and diode laser) or from a hollow tube (CO_2 and Er: YAG laser). Despite the optimization of laser tips, there are some limitations associated with their intracanal use. The laser emission is directed vertically along the optical fiber and it is almost impossible to obtain a uniform coverage of the root surface. In addition, the depth of propagation of the laser light is important as it can lead to its passage beyond the apical aperture and impact the periapical tissues. Thermal damage to the root and surrounding tissues is possible [31, 32, 33].

Laser tips with lateral radiation have been developed to improve the directions of fluid flow in the root canal during laser assisted irrigation. A conical end may be formed of a glass (quartz) basis, including one doped with fluoride, germanium or gallium, using a tubular etching process to produce increased lateral emissions. Such tips provide more laser energy to the root canal walls than to the tip of the tooth. The cone-shaped tips turn out to be better than conventional tips for removing thick layers of debris [34].

Trying to develop uniform irradiation of the walls of the root canal, changes are made in the design of the tip of the conical optical fiber. Surface micro modeling is achieved by applying a specific etching method (with hydrofluoric acid after removal of the protective polyamide coating), followed by abrasion with aluminum particles and further additional etching. This creates a series of circular veneers that resemble a honeycomb. The honeycomb tip emits a spherical emission of laser light, improving the healing effect and preventing localized thermal damage to the root dentin and periodontal tissues [35, 36, 37].

Filling the root canal system. Laser radiation as a heat source is used to soften the gutta-percha when rooting the root canal. Argon, Nd: YAG and Er: YAG lasers are particularly used for this procedure. Different studies have compared the quality of apical sealing with laser-assisted root obturation, lateral and vertical condensation, with no evidence of statistically significant differences [38, 39]. In some cases, the temperature changes on the outer root surface are disturbing - the temperature varies from 12.9°C (argon laser) to 14.4°C (Nd: YAG laser) [40]. Gekelman et al. reported a significant increase in adhesion of the material to the dentin in the root canal and reduction of its apical leakage using Nd: YAG laser (100 MJ / pulse mode, 1 W, 10 Hz) [41]. The capabilities of an Er-YAG laser (200 MJ, 4 Hz for 60 seconds) for epoxy resin silencing have also been demonstrated [42].

There is insufficient clinical evidence of the benefits of using root canal obturation lasers. Their thermal safety for the surrounding dental structures has not been clearly demonstrated. It is also not clear whether the softening of the gutta-percha is even in all parts of the filling neither, what are the most suitable wavelength and adequate parameters [5, 6].

Treatment of endodontically treated teeth. The use of lasers to remove root canal has some clinical advantages - as no toxic solvents of the canal are used, the risk of lateral perforations of the root wall in curved root canals is reduced [5, 6]. Anjo et al. reported that the root canals filling time was significantly shorter than conventional methods. However, in laser ablation with Nd: YAG lasers, some of the dentin channel openings are blocked with molten dentin [43]. The effectiveness of Er-YAG lasers in removing zinc oxide pastes and resins in straight root canals with pulsed irradiation of 250 MJ and frequency 10 Hz has also been demonstrated [44]. Cases of more effective removal of broken endodontic instruments from the root canal using an Nd: YAG laser have been reported [45]. The decisive advantage of lasers in the treatment of endodontically treated teeth remains unconfirmed [5, 6, 46, 47, 48].

Apical surgery. Hemostasis and concomitant visualization of the operative field and the potential sterilizing effect on the contaminated root surface make the laser resection of the root an area of interest for the study. Following a laser apicotomy with a CO_2 laser, a better healing process was observed compared to the standard surgical procedure [49]. Nd: YAG lasers show a decrease in bacterial penetration in the cutting area. The reduced permeability is the result of structural changes in the dentin during irradiation. The melting, hardening, and re-crystallization of hard dental tissues results in a relatively smooth surface with significantly reduced (but not completely eliminated) permeability of the dentin. Adhesion with the trimming material is improved and so is the prognosis for the tooth [50]. The cutting speed of an Er: YAG laser is less than conventional high-speed handpieces. Nevertheless, this is compensated by the lack of discomfort and vibration, as well as a lower chance of contamination at the operation site and a lower risk of injury in adjacent tissues [51]. However, setting the appropriate laser wavelength is still required [7, 52].

Various types of lasers are used in a number of endodontic procedures, such as pulp diagnosis, biological treatment, pulpotomy, root canal cleansing and disinfection, root canal obstruction, cure and apical surgery [2, 3, 5, 6, 7, 53]. Despite its wide range of applications, there is still no definitive evidence that lasers provide better treatment or greater clinical success than conventional instruments [8].

Laser devices are still relatively expensive with limited accessibility [2]. Diode lasers are cost-effective - with affordable cost and long lifetime, and also have the ability to combine different resonance frequencies and wavelengths. Despite their good technical characteristics and rapid development, they are relatively new in endodontics. Their ergonomics and ease of use in the oral cavity gives them an advantage in clinical practice and encourages new researchs [27, 54].

References:

1. He WX, Liu NN, Wang XL, He XY. The application of laser in endodontics. Zhonghua Kou Qiang Yi Xue Za Zhi. 2016 Aug;51(8):470-4.
2. Mohammadi Z. Laser applications in endodontics: an update review. Int Dent J, 2009 Feb; 59(1): 35–46.
3. Kimura Y, Wilder-Smith P, Matsumoto K. Lasers in endodontics: a review. Int Endod J, 2000 May; 33(Hc3): 173–85.
4. Cvikl B, Klimscha J, Holly M, Zeitlinger M, Gruber R, Moritz A. Removal of fractured endodontic instruments using an Nd:YAG laser. Quintessence Int. 2014 Jul-Aug;45(7):569-75.
5. Convissar Robert A. Principles and Practice of Laser Dentistry, 2nd Edition, 2015, Mosby.
6. Ingle J., Bakland I., Baumgartner J. Endodontics. 6 ed. Hamilton, Ontario, Canada, B. C. Decker, 2008.
7. .Stabholz A, Sahar-Helft S, Moshonov J. Lasers in endodontics. Dent Clin North Am, 2004 Oct; 48(4): 809–32.
8. ADA. Positions and Statements. Statement on Lasers in Dentistry. Available at: www.ada.org/1860.aspx. Accessed December 28, 2010.
9. Stefanova, W. Application of Laser Doppler Fluometry in Dental Medicine. Dental magazine, 2015, 3(8): 18–22.
10. Kijsamanmith K, Vongsavan N, Matthews B. Pulpal blood flow recorded from exposed dentine with a laser Doppler flow meter using red or infrared light. Arch Oral Biol. 2018 Mar;87:163-167.
11. Jafarzadeh H. Laser Doppler flowmetry in endodontics: a review, Int Endod J. 2009 Jun; 42(6):476-490.
12. Dogandzhiyska Violeta Dimitrova. Influence of photoactivated disinfection and Er:YAG laser on deep carious lesion (experimental and clinical - laboratory investigations). [dissertation]. Sofia, 2016.
13. Olivi G, Genovese MD, Maturo P, Docimo R. Pulp capping: advantages of using laser technology. Eur J Paediatr Dent, 2007 Jun; 8(2): 89–95.
14. Deng Y, Zhu X, Zheng D, Yan P, Jiang H. Laser use in direct pulp capping: A meta-analysis. J Am Dent Assoc. 2016 Dec;147(12):935-942.
15. Javed F, Kellesarian SV, Abduljabbar T, Gholamiazizi E, Feng C, Aldosary K, Vohra F, Romanos GE. Role of laser irradiation in direct pulp capping procedures: a systematic review and meta-analysis. Lasers Med Sci. 2017 Feb;32(2):439-448.
16. Ansari G, Safi Aghdam H, Taheri P, Ghazizadeh Ahsaie M. Laser pulpotomy-an effective alternative to conventional techniques-a systematic review of literature and meta-analysis. Lasers Med Sci. 2018 Nov;33(8):1621-1629.
17. Jeng-fen Liu. Effects of Nd:YAG laser pulpotomyon human primary molars. J Endod 2006;32:404–7.
18. Durmus B, Tanboga I. In vivo evaluation of the treatment outcome of pulpotomy in primary molars using diode laser, formocresol, and ferric sulphate. Photomed Laser Surg, 2014; 32: 289–95.
19. Pescheck A, Pescheck B, Moritz A. Pulpotomy of primary molars with the use of a carbon dioxide laser: Results of a long-term in vivo study. J Oral Laser Appl, 2002; 2(3): 165–9.
20. Mohammadi Z, Jafarzadeh H, Shalavi S, Sahebalam R, Kinoshita JI. Laser-based Disinfection of the Root Canal System: An Update. *J Contemp Dent Pract.* 2017 Jan 1;18(1):74-77.
21. Franzen R, Gutknecht N, Falken S, Heussen N, Meister J. Bactericidal effect of a Nd:YAG laser on Enterococcus faecalis at pulse durations of 15 and 25 ms in dentine depths of 500 and 1,000 μm. Lasers in Medical Science, 2011; 26(1): 95–101.
22. Ding Y, Xiao S, Yang H, Meng S. Application of Nd:YAG laser in stomatology. Hua Xi Kou Qiang Yi Xue Za Zhi. 2015 Oct;33(5):445-50.
23. Gutknecht N. Lasers in Endodontics. Journal of the Laser and Health Academy, 2008; (4): 1.
24. Jhingan P, Sandhu M, Jindal G, Goel D, Sachdev V. An in-vitro evaluation of the effect of 980 nm diode laser irradiation on intracanal dentin surface and dentinal tubule openings after biomechanical preparation: Scanning electron microscopic study. Indian J Dent, 2015 Apr-Jun; 6(2): 85–90.
25. Jurič Ivona Bago, Anić Ivica. The Use of Lasers in Disinfection and Cleanliness of Root Canals: a Review. Acta Stomatol Croat. 2014 , 48(1): 6–15.
26. Saraswathi MV, Nidambur Vasudev Ballal, Indhya Padinjaral, Subraya Bhat. Ultra morphological changes of root canal dentininduced by 940 nm diode laser: An in-vitro study. Saudi Endodontic Journal, 2012; 2 (3): 131–135.
27. Saydjari Y, Kuypers T, Gutknecht N. Laser application in dentistry: Irradiation effect of Nd:YAG 1064 nm and diode 810nm and 980 nm in infected root canals – a literature overview. Bio Med Research Int, 2016.
28. Georgieva Tzvetelina Georgieva. Possibility of photo-activated and Nd:YAG laser for elimination of Endodontic microflora. [dissertation]. Sofia, 2015.
29. Roeland JG De Moor, Maarten Meire, Kawe Goharkhay, Andreas Moritz, Jacques Vanobbergen. Efficacy of Ultrasonic versus Laser-activated Irrigation to Remove Artificially Placed Dentin Debris Plugs. Journal of Endodontics, September 2010; 36(9), 1580–1583.
30. Rajakumaran A, Ganesh A. Comparative Evaluation of Depth of Penetration of Root Canal Irrigant After Using Manual, Passive Ultrasonic, and Diode Laser-Assisted Irrigant Activation Technique. *J Pharm Bioallied Sci*. 2019 May;11(Suppl 2):S216-S220.
31. Matsumoto K. Lasers in endodontics. Dent Clin of

North Am, 2000; 44: 889–906.

32. Roy George, Ian A. Meyers, Laurence J. Walsh. Laser Activation of Endodontic Irrigants with Improved Conical Laser Fiber Tips for Removing Smear Layer in the Apical Third of the Root Canal. Original Research Article Journal of Endodontics, December 2008; 34(12): 1524–1527.
33. Stabholz A, Zeltzser R, Sela M et al. The use of lasers in dentistry: principles of operation and clinical applications. Compend, 2003; 24: 811–24.
34. George R, Meyers IA, Walsh LJ. Laser Activation of Endodontic Irrigants with Improved Conical Laser Fiber Tips for Removing Smear Layer in the Apical Third of the Root Canal. J. Endod, 2008; 34(12): 1524–1527, doi: 10.1016/j.joen.2008.08.029.
35. George R, Walsh LJ. Laser Fiber-optic Modifications and Their Role in Endodontics. J. Laser Dent, 2012; 20: 24–30.
36. George R, Chan K, Walsh LJ. Laser-induced agitation and cavitation from proprietary honeycomb tips for endodontic applications. *Lasers Med Sci*. 2015 May;30(4):1203-8.
37. George R, Walsh LJ. Thermal Effects from Modified Endodontic Laser Tips used in the Apical Third of Root Canals with Erbium-doped Yttrium Aluminium Garnet and Erbium, Chromium-doped Yttrium Scandium Gallium Garnet Lasers. Photomed. Laser Surg. 2010; 28: 161–165, doi: 10.1089/pho.2008.2423.
38. Kimura Y, Yonaga K, Yokoyama K, et al. Apical leakage of obturated canals prepared by Er:YAG laser. J Endod 2001;27:567–70.
39. Maden M, Gurgul G, Tinaz AC. Evaluation of apical leakage of root canals obturated with Nd:YAG laser-softened guttapercha, System-B, and lateral condensation techniques. Contemp Dent Pract, 2002; 15: 16–26.
40. Anic I, Matsumoto K. Dentinal heat transmission induced by a laser-softened gutta-percha obturation technique. J Endod. 1995; 21: 470–4.
41. Gekelman D, Prokopowitsch I, Eduardo CP. In vitro study of the effects of Nd:YAG laser irradiation on the apical sealing of endodontic fillings performed with and without dentin plugs. J Clin Laser Med Surg, 2002; 20: 117–21.
42. Ozkocak I, Sonat B Evaluation of Effects on the Adhesion of Various Root Canal Sealers after Er:YAG Laser and Irrigants Are Used on the Dentin Surface. *J Endod*. 2015 Aug;41(8):1331-6.
43. Anjo T, Ebihara A, Takeda A et al. Removal of two types of root canal filling material using pulsed Nd-YAG laser irradiation. Photomed Laser Surg. 2004; 22: 470–6.
44. Warembourg P, Rocca JP, Bertrand MF. Efficacy of an Er:YAG laser to remove endodontic pastes. An in vitro. J Oral Laser Appl, 2001; 1: 43–7.
45. Cvikl B, Klimscha J, Holly M, Zeitlinger M, Gruber R, Moritz A. Removal of fractured endodontic instruments using an Nd:YAG laser. Quintessence Int. 2014 Jul-Aug;45(7):569-75.
46. Yao K, Satake K, Watanabe S, Ebihara A, Kobayashi C, Okiji T. Effect of Laser Energy and Tip Insertion Depth on the Pressure Generated Outside the Apical Foramen During Er:YAG Laser-Activated Root Canal Irrigation. *Photomed Laser Surg*. 2017 Dec;35(12):682-687.
47. Granevik Lindström M, Wolf E, Fransson H. The Antibacterial Effect of Nd:YAG Laser Treatment of Teeth with Apical Periodontitis: A Randomized Controlled Trial. *J Endod.* 2017 Jun;43(6):857-863.
48. Birang R, Kiani S, Shokraneh A, Hasheminia SM. Effect of Nd: YAG laser on the apical seal after root-end resection and MTA retrofill: a bacterial leakage study. *Lasers Med Sci*. 2015 Feb;30(2):583-9.
49. Bader G, Lejeune S. Prospective study of two retrograde endodontic apical preparations with and without the use of CO2 laser. Endod Dent Traumatol, 1998; 14: 75–8.
50. Stabholz A, Khayat A, Weeks DA et al. Scanning electron microscopic study of the apical dentine surfaces lased with Nd:YAG laser following apicectomy and retrofill. Int Endod J, 1992; 25: 288–91.
51. Komori T, Yokoyama K, Takato T, Matsumoto K. Clinical application of the Er:YAG laser for apicoectomy. J Endod, 1997; 23:748–50.
52. Mohammadi Z, Jafarzadeh H, Shalavi S, Kinoshita JI, Giardino L. Lasers in Apicoectomy: A Brief Review. *J Contemp Dent Pract*. 2017 Feb 1;18(2):170-173.
53. Coluzzi DJ. Lasers in dentistry. Compend Contin Educ Dent 2005; 26(6A Suppl): 429–35.
54. Renk KF. Basic of laser physics. Optic and lasers. 2012; 18, 620 p.

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