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Comparative Efficacy of Dental Lasers versus Mouthwash in Root Canal Disinfection

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Abstract

Introduction: In the realm of endodontic treatment, innovative laser technologies are emerging as promising alternatives to traditional chemo-mechanical methods for root canal disinfection. These laser techniques are reputed to penetrate deeper into dentin, offering enhanced bacterial eradication. This systematic review seeks to explore the efficacy of dental lasers in purifying root canals during endodontic procedures.

Methods: This review was conducted through a comprehensive search on PubMed and Medline, employing a series of specific keywords. The search was confined to articles published in English. Additionally, references from relevant articles were scrutinized for inclusion. The studies selected for review spanned a range of wavelengths from 600 to 2940 nm across the electromagnetic spectrum, encompassing technologies such as LED, halogen lamps, Nd:YAG, Er, Cr:YSGG, Er:YAG, and quartz tungsten halogen with blue light laser.

Results: From the 254 articles initially identified, nine met the inclusion criteria for this systematic review. A common limitation among these studies was the lack of justification for the sample size, with no power analysis reported. Furthermore, none of the studies implemented blinding during either the treatment or the outcome evaluation phases. The review noted significant heterogeneity in the application of the laser treatments.

Conclusions: The findings indicate that dental lasers are capable of significantly reducing bacterial populations within the root canal, though sodium hypochlorite remains superior in effectiveness. However, the laser's ability to extend its antibacterial effects beyond 1mm into the dentin suggests its utility in sealing dentinal tubules and eradicating bacteria such as Escherichia coli and Enterococcus faecalis. Consequently, integrating laser treatment with conventional rinsing solutions is advocated for enhanced canal disinfection.

Keywords: Disinfection, Dental Lasers, Root Canal Treatment, Dentin Penetration, Bacterial Reduction.

Introduction

Laser technology, characterized by its unique electromagnetic radiation properties, differs significantly from natural light, which is typically white. Laser light is monochromatic, coherent, and concentrated [1]. Dental lasers can produce both visible and invisible beams, with their coherent wavelengths working in conjunction with various parameters such as wavelength, tissue physical properties, energy output, operational mode (continuous or pulsed), beam diameter, and exposure duration to impact biological tissues. As the laser beam traverses through tissue, it may be reflected, absorbed, transmitted, or scattered [2].

Advancements in laser delivery systems, including the development of slender, flexible fibers and innovative endodontic tips, have facilitated the application of laser technology in diverse endodontic treatments. The primary objective of these treatments is the thorough disinfection of the root canal system to eliminate pathogenic microbes, crucial for preventing dental pulp necrosis and the formation of periapical lesions. Despite the challenges in completely eradicating bacteria from root canals with conventional methods [3], novel strategies such as high-power laser applications and photodynamic therapy have been introduced for enhanced disinfection [4]. Traditional root canal procedures face limitations such as dependency on the practitioner's skill, lengthy treatment durations, potential weakening of teeth due to canal widening, and the use of chemicals like sodium hypochlorite. Another concern is the inadequate penetration of irrigants into the deeper sections of dentinal tubules, where bacteria often reside, highlighting the ongoing struggle against bacterial resistance and the need for new antimicrobial solutions [5, 6].

The exploration of adjunctive antibacterial therapies to complement chemo-mechanical methods aims to target residual bacteria, thereby improving healing outcomes for teeth with infected canals [7]. However, the mechanisms by which lasers achieve microbial eradication remain to be fully elucidated. The high-power diode laser, tested across various dental and disciplines, shows promise for root canal disinfection, with its effectiveness depending on the laser's interaction with specific tissue components, or chromophores, such as water, proteins, and minerals [8]. Dental lasers, spanning emission wavelengths from 488 nm to 10,600 nm, represent a nonionizing form of radiation and have been widely documented in dental research for their versatility in applications [9]. Laser techniques offer an advanced alternative for root canal disinfection, boasting deeper penetration and greater bacterial reduction compared to conventional methods. While lasers significantly diminish bacterial presence, their bactericidal efficiency varies with the laser type and operational parameters. Nd:YAG lasers are believed to eliminate bacteria primarily through thermal effects, whereas Er:YAG lasers' bactericidal action is attributed to their strong absorption by water. The parameters influencing laser's antibacterial impact include pulse duration and irradiance [11].

This review aims to assess dental lasers' efficacy in root canal disinfection as part of endodontic treatment, revealing that while lasers effectively reduce bacterial counts, sodium hypochlorite exhibits superior antimicrobial properties. Notably, laser treatment can extend its antibacterial effects beyond 1mm into the dentin, suggesting its utility in sealing dentinal tubules and eradicating pathogens like Escherichia coli and Enterococcus faecalis. Therefore, combining laser therapy with conventional rinsing solutions is recommended for comprehensive canal disinfection.

Methods

A search was conducted using PubMed and Medline using certain keywords. The following key words or combinations were used for the search strategy: 'laser' (and also 'CO_2 ', 'Er:YAG', 'Er,Cr:YSGG', 'Nd:YAG', 'Diode', and 'KTP'), 'smear layer', 'root canal', 'permeability', 'dentine' and 'scanning electron microscopy'. To supplement the PubMed search, the terms endodontics, root canal treatment, root canal therapy and laser were used to search CENTRAL and the ISI Web of Knowledge. The results of this search were limited to English language articles. Lastly, the reference lists from published articles were checked.

Moreover, we included studies that utilised various wavelengths ranged from 600 to 2940 nm of the electromagnetic spectrum (LED, halogen lamps Nd:YAG Er,Cr:YSGG Er:YAG and quartz tungsten halogen with blue light lamp). Additionally, we did not incorporate literature reviews, commentaries, interviews, updates and short communications in our inclusive criteria.

All articles were at first considered individually by two authors; non-peer-reviewed articles and those dealing with commercial laser technology were eliminated. Relevant publications were retrieved, followed by interpretation. Original scientific studies that fulfilled the selection criteria were read in full text and evaluated using a data extraction form. Findings were discussed until consensus was reached. Neither process was blinded. The quality of each included publication was assessed as high, moderate or low. All abstracts of these publications were read, and the reference lists of relevant publications were hand-searched. Ten articles were read in full text and interpreted according to a data extraction form files.

Results and discussion

The initial search process yielded 254 publications. Nine were included in the systematic review and were assessed. The main reason for the assessment of low quality was that no study reported a rationale for sample size: none presented a power analysis. None of the assessed studies reported blinding, during either the operative procedure or outcome analysis. As described later, heterogeneity in performance was extensive. When considering the use of lasers inside root canals (RC), there are a number of restrictions that cannot be overlooked. An optical fiber with a width varying between 200 μm or more can be easily introduced into the deeper areas of the RC, even in the case of a (gentle) RC curvature [12]. Care should be taken when using the fibre tip in the proximity of the apical foramen as there may be transmission of laser light beyond the foramen. Although the goal was not achieved, sufficient data were obtained to encourage further study. When the CO2 laser is used at moderate laser energies, dentinal tubules are sealed and permeability is reduced [13]. Therefore, there are no indications that the CO2 laser can be used in the RC, as this type of laser requires direct visualization of the entire canal surface for complete exposure. The different morphological findings are due to a heterogeneous distribution of laser energy along the RC. In the cervical third of the RC, the laser fibre is oriented more perpendicularly; at middle and apical thirds the laser fibre is positioned parallel to the RC wall [14].

The temperature rise in the dentine induced by the Nd:YAG laser is, in this respect, also dependent on the direction of the dentinal tubules. Dentinal tubules running parallel to the surface prevent significant heat penetration, whereas those running in a transverse direction to the surface (i.e. parallel to the laser beam) allow the penetration of heat. This finding supports a light-propagating theory for the spreading effects of laser beams in dentine [15]. The absorption of Nd:YAG laser energy is improved by the application of black ink [16]. This reduction in permeability of the dentine walls can ensure that the RC filling seals more effectively. It is thought that morphological changes caused by the Nd:YAG laser may positively influence the marginal sealing of RC fillings. The latter effects are the result of too high a thermal damage. Its wavelength is within the infrared range, and thin and flexible fibers can be used. The diode laser has lower penetration depth in the dentine than the Nd:YAG laser and, therefore, a lower risk of unwanted temperature rise in periarticular structures. At the same time, this means it is less efficient in the case of very deep infections [17]. As their wavelengths are similar, the diode laser affects RC walls only slightly differently than the Nd:YAG laser. Therefore, similar effects are to be expected, for example the closing and the opening of dentinal tubules. The diode laser may close the dentinal tubules and, in the presence of smear layer, this effect is more pronounced. The effect of the diode laser on removing the smear layer also leads to reduced apical dye leakage after obturation in vitro [18]. The effects of this nanosecond-pulsed, frequency-doubled Nd:YAG laser on dentine, demonstrated that it can achieve complete smear layer removal. The smear layer is apparently not removed and it appears that dehydration caused contraction of the remaining smear layer. More research on this wavelength is needed to clarify tissue interaction of the KTP laser with RC walls and consequent smear layer removal. With the heat resulting from laser energy accumulation, care has to be taken not to overheat the target tissue. Water mist during irradiation not only enables rapid ablation, but also provides thermal protection. When preparing the apical area with its thinner dentine walls, considerable care should be taken to avoid destroying the apical terminus of the RC [19].

Erbium lasers at ablative settings that are used too close to the apical foramen may open the foramen and ablate apical bone; it is advised that the laser fiber is kept up to 2 mm from the apical constriction. If the appropriate parameters are selected during exposure of the RC walls to the laser beam, the effects on periodontal tissues during RC preparation using Er:YAG will be minimal [20]. This is also helped by moving the fiber in a helicoidal manner along the RC walls. As only a small amount of water has to be vaporized, little energy is needed for the ablation process 88 , so safety can be optimized. Experimental studies on the efficacy of Er:YAG laser irradiation for cleaning RC walls have demonstrated that this type of laser is more effective in removing the smear layer than other types of lasers and endodontic irrigates [21].

The dentinal walls mostly show open tubules and are free of debris or a smear layer. The laser effects depend, among other factors, on the power setting, the mode of energy delivery, the type and condition of the laser, the target tissues and water cooling. As the laser is used in a circular motion while withdrawing the optical fiber (this withdrawal might otherwise have been slower or even have halted in certain areas), in some of the areas irradiated, not all of the tubules are completely open. Differences in power settings do not appear to result in significant differences in the efficacy of smear layer removal [22]. When comparing Er:YAG laser and EDTAC (EDTA and centrimide) solutions, both means of cleaning the RC wall increased the ability of RC sealers containing calcium hydroxide to adhere to human dentine [23]. Differences in power outputs, the diameter of the fiber, and the use of the fiber with or without water spray cooling appear to influence the occurrence of carbonization and cracks [24]. The obturation of a greater number of RC ramifications using gutta-percha cones and/or sealer after treatment with Er,Cr:YSGG following mechanical instrumentation has also been demonstrated. Cone-shaped fiber tips have been tested and these produce fewer thermal effects and fewer morphological changes than conventional flat-end fiber tips. Hollow fiber optic tips, with advantages including easy manufacture in different shapes, greater adaptability, low cost, and a lower loss of transmission, were also tested. However, a fiber tip with conical and spherical sections showed a larger burning area in the frontal profile in addition to producing lateral burning.

According to many studies, a better cleaning of the RC walls was achieved with this technique compared with the use of NaOCl [6, 25]. A radial-firing tip developed for the Er,Cr:YSGG, but not yet marketed, now opens up possibilities for the homogeneous removal of the smear layer from RC walls . Although the temperature increase during Er:YAG laser irradiation should not be high , melting and fusing in the opening of dentinal tubules, caused by 40 mJ of irradiation, has been noted. Irradiation durations and the energy levels in different types of laser influence morphological changes in root dentine walls.

Thermal damage may, therefore, be limited with during tissue irradiation when the laser intensity is high and the interaction time is short. At present, the ablation efficiency of this type of laser still needs further investigation. Finally, it should also be mentioned that Er:YAG and Er,Cr:YSGG lasing may create ledges, zipping, perforations and over-instrumentation in the RC due to their ablative action [26]. Proper power settings should be used to avoid ledges and even perforations where curvatures are above 15 degrees. Therefore, care should be taken when the erbium laser fiber is used in the curved RC. This also applies to the preparation of RC orifices. This vapor, at high pressure, starts expanding at high speed and provides an opening in front of the fiber for the erbium light. As the energy source stops, the vapor cools and starts condensing, while the momentum of expansion creates a lower pressure inside the bubble. Consequently the water seems to rush into the bubble from the back, causing the imploding bubble to be shaped like a sickle. It has to be emphasized that this phenomenon of formation of vapor bubbles or cavitation is specific to erbium lasers, the process is the result of liquid absorbing the specific wavelength generated by these lasers [27].

Conclusions

Results showed that although dental laser precisely reduces canal bacterial count, sodium hypochlorite was more effective. Results showed that although laser is effective in canal disinfection, sodium hypochlorite had more antimicrobial effects than certain types of laser such as Nd:YAG laser. Antimicrobial effect of this laser without the presence of photosensitizing colors along with significant increase in heat was observed. Pathogens which grow as biofilm can hardly be eliminated by direct laser irradiation. Laser light can affect bacteria further than 1mm in dentin, hence results showed that this laser is effective for sealing dentinal tubules and eliminating bacteria such as Escherichia coli and Enterococcus Faecalis. So it is recommended to use this laser with the aforementioned rinsing solution for canal disinfection.

Conflict of interests

The authors declared no conflict of interests.

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