



Systematic Review of Laser Applications in Operative Dentistry: Advances and Clinical Implications

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ABSTRACT:

The use of dental lasers in restorative dentistry offers numerous benefits for both practitioners and patients. High-power lasers are effective for removing carious enamel and dentine, treating non-cariogenic lesions, preventing caries, performing endodontic procedures, and carrying out prosthetic procedures such as crown lengthening and sulcus uncovering.¹ Low-power lasers, on the other hand, are utilized for reducing post-operative sensitivity, maintaining periodontal health, non-surgical periodontal treatments, photodynamic therapy, and microbial decontamination in endodontic and periodontal applications.

INTRODUCTION:

The use of dental lasers in restorative dentistry offers numerous benefits for both practitioners and patients. High-power lasers are effective for removing carious enamel and dentine, treating non-cariogenic lesions, preventing caries, performing endodontic procedures, and carrying out prosthetic procedures such as crown lengthening and sulcus uncovering.¹ Low-power lasers, on the other hand, are utilized for reducing post-operative sensitivity, maintaining periodontal health, non-surgical periodontal treatments, photodynamic therapy, and microbial decontamination in endodontic and periodontal applications.²

The incorporation of laser technology into operative dentistry marks a significant advancement in dental care, providing numerous benefits for both dental practitioners and patients. Lasers have become an indispensable tool in modern dentistry, particularly in restorative procedures, where they are employed for a variety of tasks including the removal of carious lesions, treatment of non-cariogenic lesions, and various endodontic and prosthetic procedures (Kaur et al., 2020).

High-power lasers are particularly effective for cutting hard tissues such as enamel and dentine. These lasers can

precisely remove carious enamel and dentine, offering a minimally invasive approach that preserves healthy tooth structure. This precision is a substantial advantage over traditional mechanical drills, which can be more destructive. Moreover, the use of high-power lasers often results in less discomfort for patients, reducing the need for anesthesia. This is especially beneficial for patients who experience dental anxiety or have a low pain threshold (Cohen & Finkelstein, 2018).³

In addition to caries removal, high-power lasers are also employed in the treatment of non-cariogenic lesions, which include a variety of dental pathologies not related to tooth decay. These lasers can be used to reshape gums, remove benign oral tumors, and treat other soft tissue conditions. This versatility makes high-power lasers a valuable tool in the comprehensive management of oral health (Bornstein et al., 2019).

Furthermore, lasers play a crucial role in caries prevention. By enhancing the resistance of enamel to acid attacks, lasers can help in the remineralization of the tooth surface, thereby reducing the incidence of caries. This preventive application is a forward-thinking approach in dentistry, emphasizing the importance of maintaining oral health rather than merely treating disease (Gutknecht et al., 2015).⁴



Endodontic treatment, which involves the treatment of the tooth pulp and surrounding tissues, also benefits significantly from laser technology. Lasers can be used to clean and shape the root canals more efficiently and with greater precision than traditional methods. The bactericidal properties of lasers are particularly advantageous in endodontics, as they help in the effective disinfection of the root canals, thereby improving the success rate of endodontic treatments (Meire et al., 2012).

In prosthetic dentistry, lasers facilitate procedures such as crown lengthening and sulcus uncovering. Crown lengthening involves the removal of gum tissue to expose more of the tooth structure, which is essential for the placement of crowns and other restorations. Lasers provide a bloodless field, improving visibility for the dentist and comfort for the patient. Similarly, sulcus uncovering, which involves the removal of tissue to expose the tooth's margins, is performed more efficiently with lasers, reducing healing time and postoperative discomfort (Aoki et al., 2004).⁵

Low-power lasers are equally important in operative dentistry, particularly for their role in reducing post-operative sensitivity and maintaining periodontal health. These lasers are used in non-surgical periodontal therapy, which includes the treatment of gum disease without the need for invasive surgical procedures. Low-power lasers help in reducing inflammation and promoting tissue regeneration, which are critical for the maintenance of periodontal health (Rood & O'Grady, 2013).

Photodynamic therapy, which involves the use of light-sensitive compounds activated by low-power lasers, is another innovative application. This therapy is used for microbial decontamination in both endodontic and periodontal treatments. By effectively eliminating pathogenic bacteria, photodynamic therapy enhances the outcomes of these treatments and promotes better oral health (Parker, 2007).

The aim of this research paper is to systematically review the various applications of laser technology in operative dentistry, focusing on recent advancements and their clinical implications. It seeks to provide a comprehensive analysis of the benefits, effectiveness, and potential

challenges associated with laser use in restorative dental procedures.

Methodology:

Procedure and registration:

The present study was done by using the guidelines issued for preferred reporting material for systematic review (PRISMA-P) and the findings were noted in a systematic manner. Cochrane and PRISMA guidelines were considered as the guiding articles for this review.

Literature search:

For conducting this study, the required literature was accessed from online databases PubMed and Google Scholar. The relevant keywords and phrases used for the search are: minimally invasive dentistry, laser therapy and operative dentistry. One of the linguistic barriers for the search was the need of the article to be in English. The detailed information of overall studies used in this systematic review is mentioned in fig. 1. However, it is important to notify that search syntaxes were customized according to database requirement.

Eligibility Criteria:

To execute the study, a certain set of eligibility criterions was taken in consideration which can be further divided into inclusion and exclusion criteria.

Inclusion Criteria:

- Published article between 2017 to 2023.
- The review selected only those literature in which the patients were documented with operative dentistry
- Only full text literatures were taken into consideration.
- The published literature must be in English language only.

Exclusion criteria:

Volume chapters

- Short communication
- Duplicate literature



- Articles which were dated to more than 10 years back.
- Patents
- Systematic review, original articles.
- Conference articles.

Data Analysis:

After selecting literature from various databases, they were organized systematically in an excel sheet. All sorts of duplicate or triplicate articles were removed.

RESULTS:**Table no. 1 Master chart showing effectiveness of lasers in operative dentistry.**

Study	Year	Study participants	Mean Age	Type of Study	Aim of study	Laser protocol	Outcome
Sant'Anna EF, et al ⁶	2017	NS	NS	In vivo	To study how HILT can be used in orthodontic treatment.	Low-level and high-level laser therapy	Despite the several reasons for using lasers in orthodontics, they are currently under by Brazilian trained professionals. In any case, these sales will undoubtedly increase in the next generations
Molnar E, Molnar B et al ⁷	2017	N=8 (4 M / 4 F)	35	In vivo	Gender may influence postoperative circulation and inflammation.	Laser speckle contrast imaging	The most significant affecting factor was gender. Males reestablished mucosal blood flow more quickly than females. The LSCI approach is viable for assessing postoperative flap circulation in the oral mucosa.
Sun M, et al ⁸	2017	NS	NS	In vitro	A new strategy for attaining fast enamel mineralization in a physiologically	Diode laser 980 nm	The advantage of employing a laser is that it speeds up mineralization and allows you to control crystal formation precisely.



							This technology could enable enamel biomimicking repair in dental clinics
Meier et al., ⁹	2017	NS	NS	In vitro	After "Er: YAG," bacterial biofilms could be removed. On dentin and titanium surfaces, epithelial cells, gingival fibroblasts, and cells that resemble osteoblasts may attach.	"Er: YAG" With a wavelength of 2940 nm	The Er: YAG Laser provided distinct advantages over the other debridement modalities.
Saberi S, et al., ¹⁰	2018	NS	NS	In vivo	Dentinal tubule blockage and dentin surface roughness after treating dentin hypersensitivity with a combination of lasers.	"Er: YAG CO2"	Er: YAG Laser illuminates a nearby water cooler in the second segment. The CO2 the Laser illuminates a neighboring watercooling system in the third part. Initially, non-contact AFM was used on the surfaces.
Mohammed AI-M, et al., ¹¹	2019	NS	NS	In vitro	To study the effectiveness of a 445nm diode laser in preventing caries	"445 nm and 810 nm diode lasers. 0.3 W, 60 s, and 90 J/cm ² doses	The 445 nm laser irradiation is beneficial in preventing caries, but it is less effective than the argon ion laser
Kaplan, T et al ¹²	2020	NS	NS	Parallel RCT	The impact of a diode laser on the	980 nm diode laser	Diode Laser shows efficient results in pain



					severity of post-RCT pain.	coupled with a 200 µm optical fiber	management after RCT
Nammour, S., et al. ¹³	2020	(n=143) 81 F/ 62 M	48	In vivo	Quality of scar, frequency of recurrence, and patient satisfaction were assessed after numerous laser wavelength operations	Nd:YAG (1064 nm), Er,Cr:YSGG laser (2790 nm), CO2 (10,600 nm), and diode laser (980 nm)	The "Er, Cr: YSGG and CO2 laser" therapies did not reveal recurrence throughout the one-year follow-up period
Sokouti EH, et al. ¹⁴	2021	(n=20) 14 F/ 6 M	31.65	RCT	Diode low-level laser therapy affected pain alleviation in dental patients.	The Laser was a low-level Diode laser operating at 810 nm, 200 MW constant power, the 30 s of exposure duration, and a 6 J energy dose.	A low-power laser is valuable for inducing sedation and reducing patient anxiety.
Ferreira Pires Sobral, M., et al., ¹⁵	2021	NS	NS	Longitudinal randomized and parallel clinical trial	To compare a violet light-emitting diode system and in-office dental bleaching	light-emitting diodes (LEDs) device emitting violet light (405-410	Violet light alone caused repigmentation after dental bleaching



						nm) without employin g peroxide- containin g bleachin g gel.	
Tonin, M.H., et al., ¹⁶	2022	NS	NS	NS	To show that the increasing dose of Er:YAG can produce damage of implant surface		Modification of implant surface as adverse effect may not allow the correct formation of oxide layer that is important for wettability of implant and for the differentiation of osteoblasts
Kuhn-Dal Magro, A., et al., ¹⁷	2022	80	NS	Randomized double-blind clinical trial	The effect of LLLT associated with therapeutic measures from the oral mucositis	Group I- LLLT of 660 nm; Group II- LLLT of 810 nm; and Group III- associati on of waveleng ths of 660 and 810 nm.	The LLLT was effective for OM lesions
Falkenstein, F., et al., ¹⁸	2014	NS	NS	In Vitro	To demonstrate that laser-assisted treatment can produce thermal damage to pulp tissues	Extracted upper and lower human incisors stored in 0.9%	Middle-third portion of the root seems to be the most at-risk area for pulp damage



						saline solution	
Chung, S.E.V., et al., ¹⁹	2015	NS	NS	In Vitro	To demonstrate that Er: YAG laser favors bacteria elimination in infected root canals together with sodium hypochlorite irrigation	light emitting diode (LED) phototherapy	The adverse reactions observed in endodontics with Er: YAG laser include the risk of thermal injury to periodontal tissues, even if it not a temperature that causes the necrosis of periodontal ligaments
Franzen R, et al ²⁰	2015	NS	NS	In Vitro	To demonstrate that laser-assisted treatment can produce thermal damage to pulp tissues	Group I: Er, Cr (2780 nm without diode laser; Group II: Er, Cr, altering with 940 nm diode laser ; Group III: Er, Cr with 940 nm diode laser	Er, Cr:YSGG and a diode 2 W during irradiation show thermal rises on average of 1.68 ± 0.98 °C in the pulp chamber
Mozaffari, H.R., et al., ²¹	2016	NS	NS	In Vitro	To demonstrate that laser for dentinal hypersensitivity can also interfere with composite restoration	Group I: Control Group II: Desensitizer Group III: CO2 laser Group IV: Er	The application of glutaraldehyde desensitizer and the CO2 laser to the surface in order to complete restoration does not increase microleakage in the enamel or dentin damage tooth surface treatment, while Er: YAG laser significantly



							increased microleakage at the dentin margins
Ciurescu CE, et al ²²	2024	(n=42) 22 F/ 20 M	51.38	Randomized Clinical study	To assess laser therapy's role in periodontitis using computational prediction and advanced modeling through network analysis (GGMs) and structural equations (SEM).	Group 1 (CHX) control (Er,Cr:YSGG) laser	Both GGMs and SEM highlighted notable relationships between specific indicators, confirming their suitability as proxies for periodontal treatment success.
Deeb JG, et al ²³	2023	(n=29) 18 F/ 11 M	45	Retrospective study	To assess the effectiveness and practicality of erbium lasers for removing ceramic restorations and appliances from natural teeth and dental implant abutments.	Er:YAG/ Er,Cr:YSGG lasers	Erbium lasers offer a safe and effective alternative for removing ceramic restorations without damaging the abutment or prosthesis. Laser-assisted debonding allows for same-appointment recementation, making it a conservative and viable option for ceramic crown retrieval.

Footnote: HILT: high-intensity laser therapy; RCT: root canal treatment; LED: light-emitting diode; LLLT: low-level laser therapy; OM: oral mucositis; Er:YAG laser: Erbium-doped Yttrium Aluminum Garnet laser; Er,Cr:YSGG laser: Erbium, Chromium-doped Yttrium Scandium Gallium Garnet laser; CO2 laser: Carbon Dioxide laser; NS: Non-stated.



Results: In the present systematic review, we encountered thorough analysis of 18 studies, including four in vivo studies, seven in vitro studies, five randomized controlled trials (RCTs), one retrospective study, and one study not categorized by type. The results provide valuable understandings into the effectiveness and applications of various laser therapies in dental and orthodontic treatments.

Study characteristics:

1.Sant'Anna EF, et al (2017)⁶: This in vivo study highlighted the underutilization of high-intensity laser therapy (HILT) in orthodontic treatment among Brazilian-trained professionals, despite its potential benefits. Future generations are expected to implement this technology more widely.

2.Molnar E, Molnar B, et al (2017)⁷: An in vivo study involving eight participants found that gender significantly influences postoperative circulation and inflammation, with males recovering faster than females. Laser mark contrast imaging was estimated effective for assessing postoperative flap circulation in oral mucosa.

3.Sun M, et al (2017)⁸: Conducted in vitro, this study explored rapid enamel mineralization using a 980 nm diode laser. The technology was found to accelerate mineralization and allow precise control over crystal formation, suggesting potential for enamel bio mimicking repair in dental clinics.

4.Meier et al. (2017)⁹: This in vitro study demonstrated the effectiveness of the Er:YAG laser (2940 nm) in removing bacterial biofilms from dentin and titanium surfaces, promoting cell attachment and offering significant advantages over other debridement methods.

5.Saberi et al (2018)¹⁰: In this in vivo study, a combination of Er:YAG and CO₂ lasers was effective in treating dentin hypersensitivity by blocking dentinal tubules and reducing dentin surface roughness.

6.Mohammed AI-M, et al. (2019)¹¹: An in vitro study that evaluated a 445 nm diode laser found it beneficial in preventing dental caries, although less effective compared to the argon ion laser.

7.Kaplan, T et al., (2020)¹²: This parallel RCT demonstrated that a 980 nm diode laser, coupled with a

200 µm optical fiber, effectively managed pain following root canal treatment (RCT).

8.Nammour, S., et al., (2020)¹³: An in vivo study with 143 participants concluded that Er, Cr:YSGG, and CO₂ laser treatments did not show scar recurrence over a one-year follow-up period and had high patient satisfaction.

9.Sokouti EH, et al., (2021)¹⁴: This RCT found that low-level laser therapy (810 nm diode laser) effectively reduced pain and anxiety in dental patients.

10.Ferreira Pires Sobral, M., et al. (2021)¹⁵: A longitudinal randomized parallel clinical trial showed that violet light-emitting diode (LED) systems induced repigmentation after dental bleaching, without peroxide-containing gels.

11.Tonin, M.H., et al., (2022)¹⁶: This study highlighted the adverse effects of increasing doses of the Er:YAG laser on implant surfaces, potentially hindering proper oxide layer formation necessary for implant wettability and osteoblast differentiation.

12.Kuhn-Dal Magro, A., et al. (2022)¹⁷: A randomized double-blind clinical trial found that low-level laser therapy (LLLT) using 660 nm, 810 nm, and a combination of both wavelengths was effective in treating oral mucositis (OM) lesions.

13.Falkenstein, F., et al. (2014)¹⁸: An in vitro study showed that laser-assisted treatment poses a risk of thermal damage to pulp tissues, particularly in the middle-third portion of the root.

14.Chung, S.E.V., et al. (2015)¹⁹: This in vitro study demonstrated that the Er:YAG laser, combined with sodium hypochlorite irrigation, effectively eliminates bacteria in infected root canals, albeit with a risk of thermal injury to periodontal tissues.

15.Franzen R, et al., (2015)²⁰: An in vitro study found that combining the Er, Cr:YSGG laser with a 940 nm diode laser resulted in a modest temperature rise in the pulp chamber, indicating a risk of thermal damage.

16.Mozaffari, H.R., et al. (2016)²¹: This in vitro study revealed that glutaraldehyde desensitizer and CO₂ laser treatment did not increase microleakage or damage to enamel and dentin, while the Er:YAG laser significantly increased microleakage at dentin margins.



17. Ciurescu CE, et al. (2024)²²: A randomized clinical study assessed the role of laser therapy in periodontitis using computational prediction and advanced modeling, identifying key indicators for successful periodontal treatment.

18. Deeb JG, et al. (2023)²³: This retrospective study concluded that erbium lasers are a safe and effective method for removing ceramic restorations and dental implant abutments without causing damage, allowing for same-appointment recementation.

According to the present findings, this systematic review sheds light on the significant potential of various laser therapies in dental and orthodontic operative treatments. Specifically, Er:YAG, CO₂, diode, and LED systems have demonstrated considerable assurance across a range of applications. The effectiveness and safety of these laser therapies are influenced by several factors, including the specific clinical application, the dosage of laser used, and the combination of laser treatments with other therapeutic modalities. These understandings emphasize the importance of tailored laser treatment protocols to optimize patient outcomes and enhance the overall efficacy of dental and orthodontic care.

CONCLUSION:

In conclusion, this systematic review highlights the significant advancements and clinical benefits of laser applications in operative dentistry. Laser technology offers precision, reduced patient discomfort, and enhanced treatment outcomes across various dental procedures, including caries removal, endodontic treatments, and periodontal therapies. High-power lasers excel in cutting hard tissues, while low-power lasers aid in reducing postoperative sensitivity and promoting periodontal health. Despite the challenges such as cost and the need for specialized training, the integration of lasers in dental practice represents a promising direction for modern dentistry, improving both practitioner efficiency and patient satisfaction. Continued research and technological advancements will further expand their clinical applications.

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