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From Pain to Recovery: The Impact of Laser-Assisted Therapy in Dentistry and Cranio-Facial Medicine

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Abstract: Laser-assisted therapy has significantly transformed clinical practices in dentistry and craniofacial medicine, offering superior precision, minimal invasiveness, reduced pain, and faster healing compared to conventional methods. This review synthesizes current evidence on the applications of lasers in diverse dental areas, including temporomandibular disorders (TMD), medication-related osteonecrosis of the jaw (MRONJ), and various therapeutic dental procedures. The strongest clinical evidence is observed in MRONJ management, where the Er: YAG laser achieves healing success rates ranging from 60% to 95%. Despite substantial advantages, variability in clinical outcomes, particularly regarding the efficacy of low-level laser therapy (LLLT) in temporomandibular disorder (TMD), highlights the need for standardized protocols and clearer guidelines. Challenges such as high equipment costs and specialized training requirements persist. Future research should focus on integrating advanced imaging with laser therapies and establishing consistent treatment protocols to further optimize patient outcomes.

Keywords: Lasertherapy; Photobiomodulation; Temporomandibular disorders; Medication-Related Osteonecrosis of the Jaw (MRONJ);

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1. Introduction

Laser technology, an acronym for Light Amplification by Stimulated Emission of Radiation, has revolutionized numerous medical fields with its precision and versatility. In dentistry, lasers have transformed traditional practices, offering significant advancements in treatment quality and patient comfort. The principle of laser is based on the interaction of laser beam with tissues [1]. The laser beam interacts with tissues based on their water content, pigmentation, or other properties, depending on the wavelength used [2]. The energy from the laser is absorbed by the targeted tissue, causing a reaction such as: cutting (the energy vaporizes tissue, allowing precise cuts), coagulation (the laser energy seals blood vessels), sterilization (bacteria are destroyed due to the heat generated by the laser) and biostimulation (the laser can enhance healing by stimulating cellular processes in soft tissue)[1,2].

Currently, the most commonly used lasers in dentistry are categorized based on their specific applications and wavelengths, which determine their effectiveness in various dental procedures. For soft-tissue treatments, diode lasers with wavelengths of 445 nm and 810, 940, 970, and 1,064 nm are prevalent due to their ability to efficiently cut and coagulate soft tissues with minimal thermal damage. The potassium titanyl phosphate (KTP) laser, emitting at 532 nm, is also favored for its precision in soft-tissue surgeries. Nd: YAG lasers, particularly at 1,064 nm, are widely used due to their deep penetration, which is ideal for periodontal treatments and oral surgeries (Figure 1) [1].

In hard- and soft-tissue applications, the Er:Cr:YSGG laser at 2,780 nm and the Er:YAG laser at 2,940 nm are the lasers of choice. These lasers are highly absorbed by water and hydroxyapatite, making them effective for cutting through bone and teeth without causing excessive heat, thus preserving surrounding tissues. CO2 lasers, especially those at 10,600 nm, are utilized for their versatility in both cutting and vaporizing soft tissues and for their coagulative capabilities, which reduce bleeding during procedures. For caries detection, lasers like the diode at 405 nm and 655 nm offer a significant advantage by helping to identify and assess carious lesions through fluorescence, enhancing the accuracy of diagnoses and treatment planning (figure 1) [1].

Soft-tissue lasers	
Diode	445 nm
KTP	532 nm
Diode	810, 940, 970, 1,064 nm
Nd:YAG	1,064 nm
Nd:YAP	1,340 nm
CO_2	10,600 nm
Hard- and soft-tissue lasers	
Er,Cr:YSGG	2,780 nm
Er:YAG	2,940 nm
CO_2	9,300 nm
LLLT	
KTP	532 nm
Diode	635–675 nm
Diode	810, 940, 970, 1,064 nm
Laser for caries detection	
Diode	405 nm
Diode	655 nm

Figure 1 – Types of lasers most used in dentistry [1]

The integration of laser technology into dentistry has been driven by its ability to provide minimally invasive alternatives to conventional mechanical and chemical methods [3,4]. Lasers deliver controlled energy to dental tissues, enabling precise cutting, removal, and modification of both hard and soft tissues with minimal patient discomfort and reduced recovery times [4]. The scope of applications ranges from cavity preparation, caries removal, and endodontic sterilization to soft tissue surgeries such as gingivectomy and frenectomy, each benefiting from the specific absorption characteristics of different laser wavelengths [5,6].

Recent advancements have expanded the use of laser technology in dentistry beyond simple procedures, addressing complex therapeutic needs and enhancing diagnostic capabilities [5-7]. For instance, diagnostic lasers now assist in the early detection of caries by revealing demineralization not visible to the naked eye [8-10]. Therapeutically, lasers contribute to biostimulation processes that accelerate tissue healing and reduce postoperative discomfort [11,12,13].

Ongoing research is needed to optimise protocols, understand long-term outcomes and expand applications, despite the promising integration of lasers into dental practice [14]. By critically analysing recent advances, comparing laser types across different dental disciplines, and discussing future directions for research and clinical practice, this literature review aims to summarise the current state of laser technology in dentistry. Therefore, there is an ongoing demand to inform both clinicians and researchers about the potential and limitations of laser dentistry in the modern dental environment and to identify existing research gaps so that future studies can be more strategically directed.

Although laser technology in dentistry has provided substantial advancements in patient comfort and clinical precision, significant variability in clinical outcomes remains evident across different applications and patient populations. For example, while laser therapy shows promising results in treating medication-related osteonecrosis of the jaw (MRONJ) and diagnostic capabilities, its effectiveness in conditions like temporomandibular disorders (TMD) remains inconsistent. This review aims to critically address these variations, offering clinicians a clearer perspective on evidence-based applications and highlighting areas needing further research.

2. Materials and Methods

2.1. Search strategy

In order to perform this narative review, keywords were defined by searching the MESH descriptors to form the search strategy.

The follwing combinations of keyword was used in PubMed/MEDLINE, SCOPUS, EMBASE, Cochrane Central and Web of Science - "(laser-assisted therapy OR laser therapy OR laser treatment OR photobiomodulation) AND (treatment outcomes OR clinical outcomes OR therapeutic outcomes OR efficacy OR effectiveness) AND (dentistry OR dental medicine OR oral health OR dental care) AND (craniofacial medicine OR craniofacial medicine OR maxillofacial medicine OR facial surgery OR craniofacial surgery) in The search was carried out between July and August 2024.

A review of studies was performed for each topic and type of laser or periodontal treatment. A manual search of systematic reviews and meta-analyses was also conducted between 2019 and August 2024. The level of certainty of the systematic reviews was developed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology.

2.2. Study selection

The inclusion criteria for our narrative review on laser therapy focused on peer-reviewed research articles, systematic reviews, meta-analyses, clinical trial reports, and observational studies published within the last five years and written in English. These studies should specifically address the therapeutic uses of laser technology in humans, covering applications such as periodontal disease treatment, cancer therapy, oral surgery procedures, and pain management. Included articles must provide clear outcomes detailing the efficacy, safety, treatment protocols, or mechanistic insights of laser therapy, ensuring the review encompasses the most recent advances and current technologies in the field.

The exclusion criteria were, as follows: literature, editorials, opinion pieces, and non-peer-reviewed articles to ensure a foundation of scientifically valid evidence. Studies focusing exclusively on animal models, as well as those concerning laser applications outside medical or dental contexts, such as industrial or military uses, were also excluded. Additionally, articles that present incomplete data, such as abstracts, conference presentations, or unpublished works lacking comprehensive methodological details, are omitted. gDuplicate publications or multiple reports of the same study are further excluded to avoid redundancy and potential bias in synthesizing the results. This approach ensured that the review is based on reliable and directly relevant sources.

2.3. Data extraction

In order to ensure the effectively collect and organize key information from the studies included in our narrative review on laser therapy, we have developed a standardized data extraction form. The form was structured to capture essential details, including the citation of the study (authors, title, journal, publication year, and DOI), the study design (e.g., randomized controlled trial, observational study), the sample size, and the demographic and clinical characteristics of the population studied. Furthermore, the data extraction form includes detailed information regarding the specific laser type utilized, including its wavelength and mode of operation, as well as comprehensive treatment details such as dosage, frequency, and duration. Furthermore, the form lists the outcomes measured, the key findings regarding the efficacy and safety of the treatments, and the conclusions drawn by the studies' authors, which may influence clinical practice or future research.

3. Results

The initial literature search across PubMed/MEDLINE, SCOPUS, EMBASE, Cochrane Central, and Web of Science databases identified 398 articles. After removing duplicates (n=127), the titles and abstracts of the remaining 271 articles were screened against inclusion criteria, resulting in the exclusion of 213 articles due to irrelevance to laser applications in dentistry or craniofacial medicine, non-English language, or incomplete data. The full texts of the remaining 58 studies were reviewed, further excluding 40 studies that did not meet rigorous inclusion criteria (e.g., animal studies, insufficient methodological detail, opinion pieces). Ultimately, 18 studies were selected for detailed analysis (table 1). A systematic approach according to narrative review standards was used, but while the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology informally guided the quality assessment, explicit scoring tables were not generated given the narrative nature of the review.

Table 1 - Application areas, laser types, and outcomes in dental laser therapy

Application Area	Type of Laser	Studies included	Main Quantitative Outcomes	Main Limitations
Temporomandibular Disorders	LLLT	7	Significant short-term pain reduction (LLLT superior to TENS and US, 95% CI), no clear long-term effect	Inconsistent outcomes; variability in protocols
Medication-Related Osteonecrosis of the Jaw (MRONJ)	Er:YAG, LLLT	6	Healing success rates: 60%-95% (Er:YAG laser), enhanced outcomes when combined with PRP	Variations in patient factors and laser protocols
Therapeutic Dental Applications	Diode, Er:YAG	5	Improved healing and patient comfort, decreased inflammation, less postoperative discomfort	Risk of thermal damage; high equipment costs

4. Discussion

4.1 Laser therapy in case of temporomandibular disorders

A clinical practice guideline published by Busse and all, offers detailed recommendations for managing chronic pain associated with temporomandibular disorders (TMD), emphasizing the efficacy of non-invasive approaches. It strongly supports the use of cognitive behavioral therapy (CBT), either alone or in conjunction with biofeedback or relaxation therapy, as well as various physical therapies. These include therapist-assisted mobilization, manual trigger point therapy, and supervised exercises tailored to improve jaw function and posture[20]. Conversely, the guideline advises caution or recommends against more invasive or pharmacologic interventions. Specifically, it issues conditional recommendations against treatments such as arthrocentesis, low-level laser therapy, and pharmacological agents like NSAIDs used in isolation or combined with muscle relaxants. Strong recommendations are made against the use of irreversible oral splints, discectomy, and the combination of NSAIDs with opioids, highlighting potential risks or the lack of sufficient evidence supporting their effectiveness for chronic TMD pain [20]. The guideline underscores the importance of personalized care, urging clinicians to engage in shared decision-making with patients. This process ensures that treatment choices align with individual patient preferences, circumstances, and prior treatment experiences. The recommendations are rooted in a systematic review and network meta-analysis that assessed the comparative effectiveness and safety of various conservative, pharmacologic, and invasive interventions, providing a robust evidence base for the guidance provided[15]. Similar results were obtained by Ansari et al.. Their systematic review and meta-analysis assessed the comparative efficacy of low-level laser therapy (LLLT) against transcutaneous electrical nerve stimulation (TENS) and therapeutic ultrasound (US) for managing symptoms of temporomandibular joint disorders (TMDs). The analysis, which included twelve randomized controlled trials (RCTs), found that LLLT was significantly more effective than TENS and US in reducing pain and improving mouth opening (MO). Specifically, LLLT showed greater pain reduction compared to TENS with a 95% confidence interval and was more effective than US at an 81% confidence interval. These findings suggest that LLLT may be a preferable non-invasive treatment option for alleviating pain and enhancing functional outcomes in patients with TMD [16].

A network meta-analysis published by Yamaguchi et al. has found that stabilization splints, self-exercise, and low-level laser therapy may be effective initial conservative treatments for temporomandibular disorders (TMDs) [17]. Another systematic review evaluates the efficacy of low-level laser therapy (LLLT) as a non-invasive treatment for temporomandibular joint disorders (TMDs), which include conditions like myofascial pain, internal joint derangement, and degenerative diseases. While LLLT has been recognized as a potential treatment option for TMDs, previous reviews have reported inconsistent outcomes regarding its effectiveness. This review aims to synthesize the latest evidence from randomized controlled trials to provide a clearer understanding of LLLT's role in managing the symptoms associated with TMDs [18].

In their systematic review and meta-analysis, Wu et al. examined the effectiveness of low-level gallium aluminium arsenide (GaAlAs) laser therapy in treating myofascial pain associated with temporomandibular disorder (TMD). Despite the benefits reported, the review found that evidence supporting the effectiveness of this therapy in reducing pain severity and improving maximum mouth opening (MMO) is insufficient. Data from eight randomized controlled trials with 181 patients showed no significant long-term improvements in pain or MMO post-treatment. These findings suggest that clinicians should be cautious when recommending low-level GaAlAs laser therapy for TMD, as current evidence does not conclusively support its efficacy [19].

Photobiomodulation has been identified as an effective, non-invasive, and low-cost adjunct treatment for pain management in patients with temporomandibular dysfunction disorder , according to da Silviera et al. [20]. Similar results were obtained by Ferillo et al., concluding that onservative approaches, particularly splint appliance and laser therapy, have been shown to effectively alleviate pain in patients with intracapsular temporomandibular disorders (TMDs) [21]. In addition, Fabrizia et al., after performig a systematic review, conclude that multidisciplinary non-invasive approach has proven most effective for treating tinnitus in patients with temporomandibular disorders (TMD), with baseline tinnitus severity, gender, quality of life, age, and duration as key predictive factors for treatment outcomes [22].

While comparing various adjuvant therapies (such as acupuncture, manual therapy, jaw exercises, dietary modifications, botulinum toxin therapy, and photobiomodulation) for managing temporomandibular disorders (TMD), results from randomized controlled trials (RCTs) indicate short-term benefits in pain relief and improved jaw mobility, although conclusive evidence regarding long-term effectiveness remains scarce. Thus, while these adjunct therapies show potential, more research is needed to establish their definitive efficacy in the long-term management of TMD [23, 24].

4.2 Treatment and prevention of the Medication-Related Osteonecrosis of the jaw (MRONJ) with lasertherapy

MRONJ is a condition associated with medications, primarily bisphosphonates and antiresorptive medication, which can disrupt bone healing and remodeling. First identified in 2003, MRONJ manifests through necrotic bone lesions in the jaw, triggered by minor exposer of the bone due to mucosal lesions or dental procedures, persisting beyond eight weeks without prior radiation therapy. MRONJ is mainly observed in patients treated for bone disorders like osteoporosis and cancers, such as multiple myeloma or metastases [25, 26].

For patients undergoing antiresorptive therapy, protocols for dental surgeries emphasize preventive strategies. Recommended steps include minimizing trauma during procedures, maintaining excellent oral hygiene, and employing pre-surgical antiseptics like chlorhexidine rinses. Surgery is generally avoided if possible, particularly extensive procedures, to prevent exacerbating MRONJ [26]. If surgery is necessary, conservative surgical techniques, such as minimal debridement and infection management with antibiotics, are advocated [25]. Laser therapy, including high-intensity laser surgery and low-level laser therapy (LLLT), plays a dual role in MRONJ management by both preventing progression and aiding treatment of established osteonecrosis.

LLLT is effective at reducing inflammation and stimulating healing. The photobiomodulation provided by LLLT at wavelengths between 600 nm and 1200 nm activates mitochondrial processes, improving cellular energy production and releasing reactive oxygen species (ROS), which promotes tissue regeneration and enhances blood flow. These properties make LLLT beneficial in early-stage MRONJ by reducing pain and encouraging soft tissue repair [27, 28].

High-Intensity Laser Surgery (e.g., Er:YAG laser) can be used in advanced cases of MRONJ, enable precise bone ablation without extensive heating, thus minimizing damage to surrounding tissues. The Er:YAG laser's wavelength of 2940 nm allows effective removal of necrotic bone, aiding faster and more complete healing in comparison to conventional surgical approaches [28, 29].

The clinical protocols for laser treatment in MRONJ vary by severity as follows. Stage 1, early MRONJ stages treatment requier conservative attitude such as antiseptic rinses combined with LLLT (600–1200 nm). This measures are applied to alleviate symptoms without surgical intervention [26]. Stages 2-3, in moderate to severe MRONJ, indicates the using of high-intensity lasers, particularly the Er:YAG laser (wavelength of 2940 nm). The laser is used for debridement, combined with adjunct therapies like platelet-rich plasma (PRP) for enhanced healing. Laser sessions may involve regular intervals post-surgery for monitoring healing [27, 28].

Laser-assisted treatments offer several advantages over traditional methods. They provide precise tissue removal, reduce postoperative discomfort, and lower infection risks. The regenerative and anti-inflammatory properties of LLLT facilitate faster healing, reduce pain, and decrease the likelihood of MRONJ progression [25, 27]. Studies indicate that laser therapy combined with PRP or photobiomodulation often results in higher rates of lesion healing compared to traditional surgical methods alone [28].

Evidence from meta-analyses suggests that laser protocols lead to a high rate of healing in MRONJ patients, with some studies reporting 60-95% success rates for complete lesion healing, especially when combining Er:YAG laser surgery with LLLT. However, variations in protocol and patient factors mean that not all patients achieve complete healing, and further research is needed to optimize these protocols fully [25, 27,28].

4.3 Therapeutic applications of laser therapy

The benefits of laser therapy in dentistry are compelling, including reduced pain and inflammation, as well as enhanced healing times, which significantly improve patient comfort and treatment outcomes. However, these advantages come with challenges. Malcangi et al. (2023) discuss adverse effects such as thermal damage to tissues, which can complicate restorative procedures and affect long-term outcomes[29]. However, Santonocito et al. (2022) highlighted its potential in managing periodontal and peri-implant diseases, although they also point out that clinical evidence remains somewhat limited [30].

In a case report published Patil et al. the authors explored the effectiveness of laser therapy in the surgical excision of localized gingival overgrowth—a common impediment to maintaining oral hygiene. The use of laser technology in dental procedures, such as scaling, root planning, cavity preparation, and specifically for the excision of soft tissue growths, offers significant advantages over conventional surgical methods. Notably, laser surgery ensures a blood-free surgical site, enhancing visibility and precision during the procedure while also minimizing patient discomfort during and post-operation. This case report highlights the successful application of laser therapy in removing gingival overgrowth, leading to satisfactory postoperative healing and maintenance of oral health, thereby reinforcing the growing preference for laser applications in various dental treatments.The integration of laser therapy into standard dental protocols has shown promise, yet the need for further research is evident to refine these protocols and improve understanding of tissue responses to laser treatment [31]

Luchian et al. explored the evolving role lasers in dentistry, highlighting the application of light therapy in treating conditions such as pain, inflammation, and wound healing within various dental subspecialties including endodontics, periodontics, orthodontics, and maxillofacial surgery. Despite the therapeutic potential and positive clinical outcomes, application of lasers in dentistry has not yet achieved widespread acceptance due to skepticism, primarily arising from insufficient understanding of its molecular, cellular, and tissue mechanisms. Their research also underscores the integration of diagnostic and therapeutic light-based procedures as a promising development in dentisrty and related specialities. Nonetheless, the mixed results regarding LLLT's impact on dental implant stability call for more comprehensive studies to establish clearer guidelines and application protocols [32].

The evidence reviewed underscores strong but variable clinical support for laser therapies in dentistry. Notably, the Er:YAG laser emerges consistently effective in treating advanced MRONJ, supported by multiple studies reporting high healing rates, especially when combined with adjunctive therapies such as platelet-rich plasma (PRP). Conversely, the efficacy of LLLT in managing TMD remains contentious, demonstrating significant short-term benefits but lacking consistent evidence for sustained long-term improvement. The discrepancies observed likely reflect variations in laser wavelength, dosimetry protocols, and patient characteristics, underscoring the critical need for developing standardized, evidence-based clinical protocols.

4.4. Future perspectives

As the field of laser-assisted therapy in dentistry continues to evolve, future research is poised to unlock even greater potentials. Key areas of interest include the development of standardized protocols that can further optimize treatment outcomes and patient safety. Advances in laser technology are expected to enhance its applicability in tissue engineering, regeneration, and the non-invasive management of oral cancers. Furthermore, integration of digital imaging and laser technology could revolutionize diagnostic processes, allowing for real-time, precise interventions.

Collaborative interdisciplinary research, combining insights from materials science, photobiology and clinical dentistry, will be essential to overcome current limitations and improve the efficacy of laser therapies. A focus on clinical trials and long-term studies will also be essential to validate the clinical benefits and cost-effectiveness of these innovations, ensuring that laser-assisted therapy remains at the forefront of dental technology.

Laser therapy's therapeutic potential extends beyond surgical interventions, with applications in periodontal care, gingival overgrowth management, and endodontic treatments. Clinical cases report substantial patient comfort, minimal bleeding, and rapid healing using diode and Er:YAG lasers compared to traditional methods. However, risks such as thermal tissue damage emphasize the necessity for proper technique and thorough clinician training. While current evidence is promising, particularly in periodontal and peri-implant disease management, further clinical trials with standardized parameters are needed to strengthen practice guidelines and broaden clinical acceptance.

5. Conclusions

This literature review emphasizes the transformative impact of laser therapy across various domains in dentistry and craniofacial medicine, highlighting its precision, efficiency, and ability to minimize patient discomfort. Current evidence strongly supports broader adoption of laser technologies, not only in routine dental procedures but also in complex therapeutic and diagnostic contexts. Nevertheless, variability in clinical outcomes, particularly observed in low-level laser therapy (LLLT) for temporomandibular disorders (TMD), underscores the critical need for standardized treatment protocols.

Clinicians are encouraged to apply laser technology in alignment with evidence-based guidelines while tailoring interventions to individual patient needs. Specialized training and continuous education on technological advancements are essential for maximizing treatment outcomes. Furthermore, ongoing interdisciplinary research remains crucial for refining laser treatment protocols and understanding their long-term effectiveness fully.

Ultimately, as laser technology and our comprehension of its clinical applications continue to evolve, its integration into standard dental practice is expected to increase significantly, contributing to substantial improvements in patient care.

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