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REVIEW ARTICLE

CONTENTS

# Advancements and applications of laser technology in modern dentistry

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## ABSTRACT
The use of lasers in dentistry has revolutionized dental procedures, providing significant advantages over traditional techniques. Lasers offer enhanced precision, reduced bleeding, faster healing times, and improved patient comfort. This review explores $CO_2$ lasers, diode lasers, Er, and Er, Cr lasers, and Photobiomodulation and Low-Level Laser Therapy (LLLT). $CO_2$ Lasers: Introduced in the 1970s, $CO_2$ lasers are effective for soft tissue surgeries such as gingivectomy and frenectomy due to their high water absorption, which allows for precise cutting with minimal damage. They also enhance enamel and dentin resistance, treat gingival hyperpigmentation, and manage peri-implantitis. Diode Lasers: These are suitable for soft tissue procedures, emitting wavelengths of 800-980 nm. Diode lasers are widely used for periodontal therapy and peri-implantitis management due to their antimicrobial properties, offering benefits like reduced bleeding and faster healing. Er and Er, Cr Lasers: Emitting at 2940 nm and 2780 nm respectively, these lasers are absorbed by water and hydroxyapatite, making them ideal for caries removal and bone contouring. They provide precise ablation with minimal thermal damage. Photobiomodulation and LLLT: These therapies use low-level lasers or LEDs to stimulate cellular function, promote healing, and reduce pain without thermal damage, making them effective for managing pain and inflammation. Overall, lasers offer significant benefits in precision, patient comfort, and healing, making them a valuable tool in modern dentistry.

**KEY WORDS:** coagulation, lasers, non invasive surgery

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## INTRODUCTION
The utilization of lasers in dentistry has revolutionized various dental procedures, offering significant advantages over traditional techniques. Lasers provide unparalleled precision, reduced bleeding, faster healing times, and enhanced patient comfort, making them a preferred choice for many dental applications. This document delves into the different types of dental lasers, including CO2 lasers, diode lasers, Er, and Er,Cr lasers, as well as the emerging fields of Photobiomodulation and Low-Level Laser Therapy (LLLT), outlining their specific applications and benefits in modern dental practice.

## AIM
The aim of this study is to describe and discuss the use of lasers in modern dentistry, highlighting their advantages and disadvantages compared to conventional methods.

## MATERIALS AND METHODS
This study is based on a review of scientific literature on laser therapy. It includes articles from the past 25 years, encompassing original research, systematic reviews, and meta-analyses. The focus is on the use of lasers for aiding in healing as well as their broad application in soft and hard tissue surgery.

## REVIEW

### TYPES AND APPLICATIONS OF DENTAL LASERS
$CO_2$ laser has been a significant tool in dentistry since its introduction in the 1970s, primarily for soft tissue applications. It is a gas mixture (primarily carbon dioxide) which is used in its mechanism. $CO_2$ laser emits at a wavelength of 10,600 nm [1]. These are primarily used for soft tissue surgeries due to their high water absorption, leading to efficient cutting and coagulation with minimal damage to surrounding tissues. It is effective for both soft and hard tissues due to its high absorption in water and hydroxyapatite. Provides precise cutting and vaporization with minimal thermal damage to surrounding tissueswhen used properly [2]. These lasers can be used not only in surgery, including gingivectomy, frenectomy, and treatment of oral lesions such as leukoplakia, erythroplakia, and lichen

planus as they offer precise cutting with minimal bleeding due to their excellent hemostatic properties [3, 4] but also in caries prevention. $CO_2$ lasers enhance the resistance of enamel and dentin to acid demineralization. They can also inhibit the progression of existing carious lesions and improve the longevity of composite restorations by reducing caries around them [3, 5]. The laser is also effective in treating gingival hyperpigmentation. Provides a non-invasive method to achieve aesthetic improvements in patients with excessive melanin deposits in their gums. Studies show significant patient satisfaction with minimal pain and quick healing [6]. $CO_2$ lasers are increasingly used in the treatment of peri-implantitis due to their precise ablation properties and ability to disinfect implant surfaces. The high absorption of $CO_2$ lasers in water and hydroxyapatite makes them effective for soft tissue debridement and bone contouring around implants. $CO_2$ lasers are a versatile and valuable tool in modern dentistry, offering numerous benefits for both soft and hard tissue procedures. Their precise control, reduced patient discomfort, and enhanced healing make them a preferred choice for various dental applications, although they require proper training and careful handling to avoid potential risks.

Diode Laser is suitable for soft tissue procedures and uses semiconductor diodes. Emission wavelengths typically range from 800-980 nm and is primarily absorbed by melanin and hemoglobin [7]. Diode Lasers are widely used for soft tissue procedures, including gingivectomy, frenectomy, and periodontal therapy. They offer benefits like reduced bleeding, pain, and faster healing times [8, 9] and have become increasingly popular in dentistry due to their versatility, ease of use, and relatively low cost compared to other types of lasers. As well as Co2 lasers, diode lasers are frequently used for soft tissue surgeries such as gingivectomy, frenectomy, and tissue contouring. They are effective in cutting and coagulating soft tissues with minimal bleeding [8, 9]. As well as $CO_2$ lasers they are used in caries and gingival depigmentation treatment. Diode lasers also play a crucial role in the management of periimplantitis due to their antimicrobial properties and ability to decontaminate implant surfaces. The laser energy helps to remove bacterial biofilms from the implant surfaces, which is essential for the successful treatment of peri-implantitis [10, 11]. The anti-inflammatory properties of diode lasers help to reduce inflammation in the peri-implant tissues. This can result in improved healing and regeneration of the tissues around the implant [8].

Er and Er, Cr Lasers (Erbium-doped Yttrium Aluminium Garnet) and Er, Cr(Erbium, Chromium-doped Yttrium Scandium Gallium Garnet) lasers operate by emitting high-intensity light at specific wavelengths, primarily targeting water and hydroxyapatite in dental tissues. ErLaser emits light at a wavelength of 2940 nm, while Er, Cr Laser emits light at a wavelength of 2780 nm. These wavelengths are highly absorbed by water, making them effective for both hard and soft tissue procedures. The laser energy is absorbed by the water content in the tissues, causing rapid heating and vaporization of water molecules. This results in micro-explosions that precisely ablate the target tissue with minimal thermal damage to surrounding areas [12]. The lasers are also absorbed by hydroxyapatite, a mineral found in teeth and bone. This allows for effective cutting and reshaping of hard dental tissues without excessive heat buildup, which could damage surrounding tissues [13]. They are widely used in dentistry for various applications due to their specific wavelength characteristics and interactions with dental tissues. These are effective for caries removal, cavity preparation, and etching. The ablation process removes diseased or unwanted tissue through precise vaporization. The coagulative effect helps in controlling bleeding by sealing small blood vessels, making it particularly useful for soft tissue procedures. These lasers often incorporate a cooling system, such as a water spray or air cooling, to manage the heat generated during the procedure and to further minimize thermal damage to adjacent tissues [12]. The precise ablation capabilities make Er and Er, Cr lasers suitable for removing caries and preparing cavities without the need for anesthesia in many cases. Their ability to cut and coagulate makes them ideal for procedures like gingivectomy, frenectomy, and periodontal debridement. They are perfectly effective for bone contouring and other hard tissue modifications due to their interaction with hydroxyapatite.

Photobiomodulation and Low-Level Laser Therapy (LLLT): are therapeutic techniques that utilize low-level lasers or light-emitting diodes (LEDs) to stimulate cellular function and promote healing, pain relief, and tissue regeneration without causing thermal damage. These therapies have found increasing applications in dentistry due to their non-invasive nature and efficacy. LLLT works by delivering photons to the cells, which are absorbed by the mitochondria. This process enhances ATP (adenosine triphosphate) production, leading to increased cellular energy and metabolic activity. LLLT promotes vasodilation, which increases blood flow to the treated area, facilitating the delivery of oxygen and nutrients, and removal of waste products. This accelerates the healing process [10]. The therapy reduces the levels of pro-inflammatory cytokines and increases anti-inflammatory cytokines. This helps in reducing inflammation and pain in the treated area. LLLT is effective in reducing pain associated with various dental procedures, including tooth extractions, implant placements, and orthodontic adjustments. It is also used for managing temporomandibular joint disorders (TMD) and myofascial pain [9]. Numerous oral disorders have shown significant improvement with the use of low-intensity lasers. When combined with antibiotics, these lasers can enhance the treatment outcomes for patients suffering from bisphosphonate-related osteonecrosis of the jaw (BRONJ) and medication-related osteonecrosis of the jaw (MRONJ), effectively reducing clinical symptoms [8].

## DISCUSSION

Studies have shown mixed results regarding the effectiveness of lasers as an adjunct to mechanical therapy. Some studies indicate significant improvements in clinical and microbiological parameters when lasers are used, while others suggest no additional benefits over conventional methods [1, 7]. However, the precision and disinfection properties of lasers make them a promising option. The coagulative properties minimize bleeding, improving visibility and reducing the need for sutures [8, 9]. Faster healing times due to reduced inflammation and less trauma to tissues has been observed [8]**.** In a review of current literature authors noticed less postoperative pain and swelling, leading to higher patient comfort for the patient [10]. Laser-Assisted Treatment for Gingival Melanin Hyperpigmentation has been also more satisfying for patients, healing time has been shortened [6]. In the study presented by Romeo U., et al. in the evaluation of the effectiveness of using diode lasers as a protocol to excise leukoplakia, patients experienced a light burning sensation during the procedure [8]. The previous limitations of using $CO_2$ lasers in surgery due to the bulky delivery arm have been resolved with the introduction of Photonic Band Gap Fiber Assembly (PBFA). This innovation allows for flexible fiber delivery of $CO_2$ lasers, enhancing the surgeon's ability to effectively visualize and access the head and neck areas during procedures [8]. A study by Xue VW et al. demonstrated that a carbon dioxide laser with a wavelength of 10,600 nm effectively inhibited biofilm growth and decreased bacterial viability. However, there is a lack of research on the use of a 9,300 nm carbon dioxide laser for similar purposes, indicating a need for future studies to explore its potential [14]. The same group of researchers says that laser-activated fluoride therapy lowered the critical pH level at which enamel dissolves, suggesting a synergistic effect in caries prevention when combining laser irradiation with fluoride treatment. The research indicated that the beneficial effects span across visible and near-infrared wavelengths, including those of carbon dioxide lasers. Additionally, a clinical trial demonstrated that using a 9,600 nm carbon dioxide laser in conjunction with fluoride varnish application promoted remineralization and prevented the development of fissure caries in molars [14]. Laser techniques have been found more effective in reducing bacterial load in periodontal pockets [9]. Significant reduction in gingival inflammation, improving overall periodontal health has also been noticed [10]. Cavity preparation using Er and Er,Cr lasers are effective in precisely removing decayed tissue without affecting the surrounding healthy structure which is a big advatage comparing to traditional drilling technique**.** Lasers also create micro-retentive surfaces that enhance the bonding strength of restorative materials, while mechanical drills are effective but less precise, potentially removing more healthy tissue than necessary. The fracture mode was examined separately for laser irradiation and thermocycling procedures using a Chi-Square test. The analysis showed no statistically significant differences, with a p-value of 0.136 for laser irradiation and 0.091 for thermocycling [12]. A meta-analisys by Schwarz et al. showed that lasers, particularly Er, improved clinical parameters such as probing depth and attachment levels in periodontal therapy compared to traditional scaling and root planing (SRP) [1]. In a retrospective analysis by Mettraux, the effectiveness of using adjunctive laser irradiation in non-surgical peri-implant therapy was examined. The study involved treating 23 infected implant sites with probing pocket depths (PPD) greater than 5 mm using conventional mechanical debridement and sterile saline rinsing. Additionally, diode laser irradiation was applied around the implant pockets. This protocol was conducted at the start and repeated after 7 and 14 days. After a 2-year observation period, the researchers observed significant improvements in peri-implant health, including notable reductions in clinical attachment level (CAL), probing pocket depth (PPD), bleeding on probing (BOP), and sulcular suppuration [1, 15]. Renvert conducted a randomized controlled trial with 42 patients divided equally into control and test groups to compare the effectiveness of abrasive air-flow therapy versus Er laser therapy. After six months, the study found no statistically significant differences between the two groups in terms of bleeding on probing and probing depth **[9].** In many dental fields the fact that procedures using lasers generally result in less pain and discomfort during and after treatment is beneficial for pediatric and anxious patients.

## CONCLUSSIONS

While traditional methods are still effective and widely used, the benefits of laser treatments make them an increasingly popular choice in modern dental practice. Traditional techniques such as mechanical drills and scalpels are effective but often involve more extensive tissue damage, longer healing times, and greater discomfort for patients. The choice between laser and traditional methods should be based on the specific clinical situation, the dentist's expertise, and the patient's preferences. Factors such as the type of procedure, the patient's medical history, and their comfort level with different treatment options should be considered when determining the best approach. For instance, while lasers are highly effective for soft tissue procedures, traditional methods may still be preferred for certain types of hard tissue work where mechanical precision is paramount.

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## CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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