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Lasers in advanced clinical dental practice: A review

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Abstract:
Conventional soft tissue surgical techniques in dentistry are often limited by inadequate precision, increased intraoperative bleeding and post-operative discomfort, underscoring the need for more effective and minimally invasive approaches such as diode laser technology in clinical practice. Therefore, it is of interest to evaluate the expanding role of diode lasers, focusing on their clinical applications, advantages, limitations and future scope. Diode lasers are widely employed in soft tissue interventions such as frenectomy, gingivectomy, operculectomy, lesion excision and biopsies, offering benefits like enhanced haemostasis, reduced bleeding, minimal post-operative discomfort and accelerated healing. Thus, data shows that diode lasers represent a valuable adjunct in clinical practice, though further standardised research is necessary to optimise their application.

Keywords: Laser dentistry, photobiomodulation, minimally invasive dentistry (MID), advanced clinical dentistry, laser-tissue interaction, clinical practice

Background:
The inclusion of lasers in oral and maxillofacial surgery has been since the mid-1960s **[1]**. A laser is a device that emits light (electromagnetic radiation) through a process of optical amplification based on the stimulated emission of photons **[2]**. The clinical application of the diode laser seems to have beneficial effects in surgery. The laser provides precise and rapid tissue dissection, excellent haemostasis and lessens

post-operative inflammation **[3]**. The possibility to use diode lasers in surgical procedures on soft oral tissues is due to the absorption of laser beam by tissue pigment and haemoglobin while it is poorly absorbed by hydroxyapatite and water **[4]**. Diode lasers are especially used in aesthetic procedures such as gingival recontouring and gingival depigmentation, periapical surgery, operculectomy and pro-prosthetic surgical procedures such as remodelling of mucosa on edentulous sites, dental crown lengthening, frenectomies and vestibuloplasty **[5]**. The most researched wavelengths of diode lasers re 808nm, 810nm and 940nm **[6]**. Therefore, it is of interest to present an overview of the applications and outcomes of diode laser use in clinical dentistry.

Principles of laser technology:

In 1917, Albert Einstein put forward a theory of "stimulated emission" stating that photons could "stimulate" the emission of another photon that would possess identical properties to the first **[7]**. This concept became the scientific foundation for the development of laser technology. The term LASER stands for Light Amplification by Stimulated Emission of Radiation, referring to the generation of a highly organized beam of light through the amplification of photons within an active medium. A laser system typically consists of an active medium, an external energy source (pump) and an optical resonator formed by two mirrors. When energy is supplied to the active medium, its atoms become excited and subsequently release photons. These photons stimulate the emission of additional photons with the same wavelength, phase and direction, resulting in a coherent and concentrated beam of light **[8].** Laser light possesses unique characteristics that distinguish it from ordinary light. It is monochromatic, meaning it consists of a single wavelength; coherent, with all light waves oscillating in phase; and collimated, allowing the beam to remain parallel with minimal divergence over a distance. These properties enable precise delivery of energy to targeted tissues while minimizing damage to adjacent structures **[9]**. The biological effects of laser irradiation depend on factors such as wavelength, power output, exposure time and the optical properties of the target tissue. When laser energy interacts with oral tissues, it may be reflected, transmitted, scattered, or absorbed, with absorption producing the desired clinical effects, including cutting, coagulation, vaporization, or biostimulation. The selective interaction between specific wavelengths and tissue chromophores, such as water, haemoglobin and melanin, determines the clinical applications and effectiveness of different laser systems in oral and maxillofacial surgery **[10].**

Mechanism and interaction:

There are five interaction mechanisms associated with the use of lasers in biomedicine:

Optical effect*:*

Fluorescence spectroscopy for cancer screening, optical coherence tomography (OCT) for high-resolution imaging. The optical effect of laser–tissue interaction occurs when laser light is reflected, transmitted, scattered, or absorbed without causing significant thermal damage to the target tissue. These interactions have important diagnostic applications in oral and maxillofacial practice **[11]**. One of the most widely utilized optical techniques is fluorescence spectroscopy, which detects differences in the natural fluorescence emitted by healthy and diseased tissues following laser excitation. Alterations in tissue metabolism and structural composition enable the identification of potentially malignant and malignant lesions, making fluorescence spectroscopy a valuable adjunct for early oral cancer screening. Another important application is optical coherence tomography (OCT), a non-invasive imaging modality that uses low-coherence light to generate high-resolution, cross-sectional images of oral soft tissues. OCT allows real-time visualization of epithelial and subepithelial structures, facilitating the assessment of tissue architecture, lesion depth and disease progression without the need for ionizing radiation. These optical techniques enhance diagnostic accuracy, support early disease detection and aid clinicians in treatment planning while preserving tissue integrity **[12].**

Photomechanical effect:

Photomechanical effect (photoacustic) *i.e.* for laser lithotripsy, removal of tattoos and certain pigmented lesions. The photomechanical, or photoacoustic, effect occurs when laser energy is delivered in extremely short, high-intensity pulses, generating rapid expansion and contraction within the target tissue **[13]**. This process creates acoustic or shock waves that mechanically disrupt the tissue without producing extensive thermal injury. Unlike photothermal effects, where heat is the primary mechanism of action, the photomechanical effect relies on mechanical forces to fragment or disintegrate the target. This principle is widely employed in laser lithotripsy, where shock waves break urinary or salivary calculi into smaller fragments that can be removed or expelled more easily. In dermatological and oral applications, the photoacoustic effect is also used for the removal of tattoos and pigmented lesions by selectively disrupting pigment particles, which are subsequently cleared through the body's immune system. The controlled nature of this interaction minimizes damage to surrounding healthy tissues, promotes faster recovery and improves treatment precision, making it an important mechanism in several minimally invasive laser-based procedures **[14]**.

Photochemical effect:

Photochemical effect *i.e.* photodynamic therapy (PDT), chemical reaction stimulation, composite resin polymerization. The photochemical effect occurs when laser light initiates a chemical reaction within the target tissue without generating significant heat. This interaction depends on the activation of light-sensitive molecules, known as photosensitizers, which absorb laser energy and trigger biochemical changes. One of the most important clinical applications of this mechanism is photodynamic therapy (PDT), where a photosensitizing agent is selectively taken up by abnormal or diseased cells and subsequently activated by a laser of an appropriate wavelength. The activated photosensitizer produces reactive oxygen species that destroy targeted cells while preserving the surrounding healthy tissues. In dentistry, PDT has been used as an adjunctive treatment for periodontal infections, peri-implant diseases and selected oral potentially malignant disorders due to its antimicrobial and anti-inflammatory effects. The photochemical effect is also utilized in the polymerization of light-cured composite resin materials, where laser or visible light activates photoinitiators to achieve controlled hardening of restorative materials. These applications demonstrate the versatility of photochemical interactions in both therapeutic and restorative dental procedures **[15]**.

Photothermal effect:

Photothermal effect *i.e.* laser resurfacing, treatment of vascular lesions, laser hair removal**.** The photothermal effect is the most widely utilized mechanism of laser–tissue interaction in oral and maxillofacial surgery. It occurs when laser energy is absorbed by tissue chromophores, such as water, haemoglobin, or melanin and converted into heat. The extent of the thermal response depends on the wavelength, power density, exposure time and the optical properties of the target tissue. Controlled heat generation can produce various biological effects, including coagulation, vaporization, carbonization, or tissue ablation, making lasers suitable for a wide range of surgical procedures. In clinical practice, the photothermal effect is employed for laser resurfacing, treatment of vascular lesions through selective coagulation of blood vessels and laser hair removal by targeting melanin within hair follicles. In dentistry, this mechanism is responsible for precise soft tissue incision, effective haemostasis, bacterial reduction and minimal post-operative discomfort. When appropriate laser parameters are selected, the photothermal effect enables efficient tissue removal while limiting collateral damage, thereby promoting predictable healing and improved clinical outcomes **[17]**.

Photobiostimulative:

The Photobiostimulative effect refers to the biological response produced when low-intensity laser energy interacts with living tissues without causing a significant rise in temperature. Unlike photothermal or photomechanical effects, this mechanism does not result in tissue ablation or destruction. Instead, the absorbed light energy stimulates cellular activity by interacting with intracellular chromophores, particularly within the mitochondria. This interaction enhances the production of adenosine triphosphate (ATP), the primary source of cellular energy, leading to increased cellular metabolism, proliferation and protein synthesis. As a result, various physiological processes involved in tissue repair and regeneration are accelerated. In oral and maxillofacial practice, the photobiostimulative effect has been widely utilized to promote wound healing, reduce post-operative pain and minimize inflammation following surgical procedures. It has also been reported to enhance collagen synthesis, improve microcirculation and support angiogenesis, thereby facilitating faster tissue regeneration. Clinically, this effect has found applications in the management of oral mucositis, temporomandibular disorders, recurrent aphthous ulcers, nerve injuries and post-operative soft tissue healing. Since low-level laser therapy acts without producing thermal damage, it offers a safe and minimally invasive approach for improving patient recovery and comfort. Owing to its ability to enhance natural healing processes and reduce treatment-related morbidity, the Photobiostimulative effect has become an important adjunct in contemporary oral and maxillofacial care **[18].**

Photobiomodulative effect:

Photobiomodulative effect *i.e.* low-level laser therapy (LLLT), laser acupuncture, collagen remodelling for aged skin, anti-inflammatory treatments, blue light therapy for acne treatments, accelerated wound healing. Photobiomodulative effect the photobiomodulative effect is a non-thermal interaction in which low-intensity laser light influences cellular and molecular processes without causing tissue ablation or irreversible damage. This effect is achieved using low-level laser therapy (LLLT), where light of an appropriate wavelength is absorbed by intracellular chromophores, particularly cytochrome c oxidase within the mitochondria. The absorbed energy enhances adenosine triphosphate (ATP) production, modulates reactive oxygen species and regulates the release of cytokines and growth factors, thereby promoting cellular repair and maintaining tissue homeostasis. These biological responses collectively contribute to pain relief, reduction of inflammation and accelerated tissue regeneration **[3]**. In oral and maxillofacial practice, photobiomodulation has gained considerable attention as an adjunctive therapeutic modality for enhancing post-operative recovery and improving clinical outcomes. It is widely employed to promote wound healing, reduce edema, alleviate pain following surgical procedures and support regeneration of injured soft tissues and peripheral nerves. Beyond dentistry, photobiomodulation has showed clinical utility in laser acupuncture, collagen remodelling for skin rejuvenation, anti-inflammatory therapies and blue light–based management of acne by reducing bacterial load and sebaceous gland activity. The technique is non-invasive, well tolerated and associated with minimal adverse effects when appropriate treatment parameters are used. Owing to its ability to modulate biological processes rather than destroy tissues, photobiomodulation has become an important component of contemporary laser therapy, with expanding applications in both dental and medical practice.

Types of lasers in dentistry:

Diode lasers – These semiconductor lasers are widely preferred for soft tissue procedures because they are efficiently absorbed by haemoglobin and melanin. Diode lasers are semiconductor-based laser systems that have become an integral part of modern dental practice because of their versatility, compact design and ease of operation. They typically operate within a wavelength range of 800–980 nm, with 810 nm, 940 nm and 980 nm being the most commonly used wavelengths in dentistry. These lasers exhibit a high affinity for pigmented tissues, particularly haemoglobin and melanin, making them highly effective for soft tissue procedures while demonstrating minimal interaction with dental hard tissues. This selective absorption enables precise tissue incision, coagulation and decontamination with excellent haemostasis and reduced collateral tissue damage. Clinically, diode lasers are extensively employed for frenectomy, gingivectomy, operculectomy, gingival depigmentation, crown lengthening, biopsy procedures and the excision of benign soft tissue lesions. They are also used as an adjunct in periodontal therapy and peri-implant disease management because of their antimicrobial properties. Additional advantages include reduced intraoperative bleeding, minimal post-operative pain and edema, faster wound healing and improved patient comfort, making diode lasers a valuable tool in contemporary oral and maxillofacial practice **[20]**.

Carbon dioxide (CO_2) lasers – Known for their strong interaction with water, these lasers allow precise soft tissue removal with excellent control over bleeding. Carbon dioxide (CO_2) lasers are among the earliest and most extensively studied laser systems used in dentistry and oral and maxillofacial surgery. They operate at a wavelength of 10,600 nm, which is highly absorbed by water, the principal component of soft tissues. This characteristic enables precise vaporization and incision of soft tissues while limiting the depth of penetration into adjacent structures. The excellent haemostatic effect achieved through coagulation of small blood vessels provides a clear surgical field and reduces intraoperative bleeding. CO_2 lasers are commonly used for the excision of benign and premalignant oral lesions, gingivectomy, frenectomy, vestibuloplasty, operculectomy and soft tissue biopsies. Their bactericidal properties also contribute to a reduced risk of post-operative infection. In addition, patients often experience less post-operative pain, edema and scarring compared with conventional scalpel surgery, resulting in improved healing and patient comfort. However, careful adjustment of laser parameters is essential to prevent excessive thermal injury and ensure optimal clinical outcomes during soft tissue procedures **[21]**.

Nd: YAG lasers – Due to their deeper penetration and affinity for pigmented tissues, they are commonly used in periodontal therapy and microbial reduction. Neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers operate at a wavelength of 1064 nm and are characterized by their deep tissue penetration and high affinity for pigmented chromophores such as melanin and haemoglobin. These properties make them particularly effective for soft tissue procedures requiring coagulation, decontamination and microbial reduction. In dentistry, Nd:YAG lasers are frequently used as an adjunct in periodontal therapy to eliminate pathogenic bacteria within periodontal pockets, promote pocket decontamination and support soft tissue healing. They have also been employed for gingivectomy, treatment of vascular lesions, sulcular debridement and management of peri-implant diseases. The excellent haemostatic properties of Nd:YAG lasers provide a bloodless surgical field, improving visibility during clinical procedures. Additionally, their bactericidal effect contributes to reduced post-operative infection and enhanced wound healing. Despite these advantages, the deeper penetration of laser energy necessitates careful selection of operating parameters to minimize the risk of thermal injury to surrounding tissues and underlying bone **[22]**.

Er: YAG lasers – With high absorption in water and hydroxyapatite, these lasers are suitable for a range of hard and soft tissue procedures. Erbium-doped yttrium aluminum garnet (Er:YAG) lasers operate at a wavelength of 2940 nm and are characterized by their high absorption in both water and hydroxyapatite, making them highly effective for hard and soft tissue applications. This unique absorption profile allows efficient tissue ablation with minimal thermal penetration, thereby reducing the risk of collateral tissue damage. In restorative dentistry, Er:YAG lasers are widely used for cavity preparation, caries removal, enamel and dentin conditioning and the removal of restorative materials. Their ability to precisely ablate mineralized tissues with minimal vibration and discomfort often reduces the need for local anaesthesia, thereby improving patient acceptance. In oral and maxillofacial surgery, Er:YAG lasers are employed for gingivectomy, frenectomy, operculectomy, soft tissue lesion excision, peri-implantitis management and bone contouring. They have also showed excellent bactericidal properties, contributing to effective decontamination of surgical sites and promoting favourable wound healing. Compared with conventional rotary instruments, Er:YAG lasers produce less noise, vibration and mechanical trauma, enhancing patient comfort during treatment. Furthermore, the limited thermal effect preserves surrounding healthy tissues, resulting in reduced post-operative pain, edema and faster tissue repair. Owing to their versatility, precision and safety profile, Er:YAG lasers have become an important component of minimally invasive dental and oral surgical procedures **[23].**

Er, Cr: YSGG lasers – These lasers offer versatility in clinical practice, enabling efficient cutting of hard tissues along with gentle soft tissue management. Erbium, chromium-doped yttrium scandium gallium garnet (Er, Cr:YSGG) lasers operate at a wavelength of 2780 nm and are recognized for their versatility in both hard and soft tissue procedures. Their laser energy is highly absorbed by water and hydroxyapatite, allowing efficient cutting of enamel, dentin, bone and soft tissues while minimizing thermal injury to adjacent structures. These lasers utilize a hydrokinetic mechanism, in which laser energy interacts with a fine spray of water to facilitate precise tissue ablation with minimal mechanical trauma. This feature enhances cutting efficiency while maintaining tissue hydration and reducing the risk of overheating. In dentistry, Er, Cr:YSGG lasers are commonly employed for cavity preparation, caries removal, osseous recontouring, crown lengthening, gingivectomy, frenectomy, implant site preparation and soft tissue excision. Their ability to provide excellent surgical precision with reduced vibration and noise improves patient comfort and frequently decreases the need for local anaesthesia. In addition, the bactericidal effect of Er, Cr:YSGG lasers contributes to improved

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decontamination of the operative field and supports favourable wound healing. Reduced post-operative pain, edema and bleeding further enhance clinical outcomes following laser-assisted procedures. Owing to their broad range of applications and minimally invasive nature, Er, Cr:YSGG lasers have become an important technology in contemporary restorative, periodontal and oral surgical practice **[24]**.

Argon lasers – Emitting blue-green light, they are mainly utilized for soft tissue applications and for curing certain dental restorative materials. Argon lasers emit blue-green light at wavelengths of 488 nm and 514 nm, which are selectively absorbed by pigmented tissues and haemoglobin. This selective absorption makes them particularly effective for soft tissue procedures requiring precise coagulation and haemostasis. In dentistry, argon lasers have been used for gingival contouring, management of vascular lesions, soft tissue excision and control of intraoperative bleeding. Their affinity for haemoglobin allows efficient coagulation of small blood vessels, providing a clear surgical field and reducing blood loss during treatment. In addition to soft tissue applications, argon lasers have been employed for the polymerization of light-cured composite resin materials. The wavelength emitted by these lasers effectively activates photoinitiators within resin-based restorative materials, resulting in rapid and uniform polymerization with improved physical properties **[25]**. Argon lasers have also been investigated for caries prevention by enhancing enamel resistance to acid demineralization and reducing bacterial adherence. Despite these clinical advantages, their use in contemporary dental practice has declined because of the availability of newer laser systems that offer greater versatility and broader clinical applications. The relatively large size, high cost and maintenance requirements of argon laser units have further limited their routine use. Nevertheless, argon lasers remain valuable for selected soft tissue and restorative procedures where precise coagulation and effective light activation are required.

Laser parameters and factors influencing clinical outcomes:

Wavelength:

Wavelength is one of the most important parameters in laser dentistry, as it determines the depth of tissue penetration and the type of tissue with which the laser interacts. Different wavelengths exhibit varying affinities for chromophores such as water, haemoglobin and melanin, thereby influencing the clinical effect and the selection of the appropriate laser system for specific dental procedures **[9]**. Proper wavelength selection ensures precise tissue targeting, minimizes collateral thermal damage and enhances the safety and effectiveness of laser-assisted treatment **(Table 1)**.

Power output:

Power output refers to the amount of laser energy delivered per unit time and directly influences the extent of tissue interaction and clinical effectiveness. Appropriate power settings ensure efficient tissue cutting or coagulation while minimizing excessive thermal damage to surrounding structures **[25]**.

Pulse duration:

Pulse duration is the length of time for which laser energy is emitted during a single pulse and influences the amount of heat transferred to the target tissue. Selecting an appropriate pulse duration helps achieve precise tissue ablation while minimizing collateral thermal damage and promoting favorable healing **[23]**.

Energy density (fluence):

Energy density, also known as fluence, refers to the amount of laser energy delivered per unit area of tissue (J/cm²) and is a key determinant of the biological response. Appropriate fluence ensures effective tissue ablation or biostimulation while minimizing unnecessary thermal injury to surrounding tissues.

Spot size:

Spot size refers to the diameter of the laser beam at the point of tissue contact and influences the concentration of energy delivered to the target area. A smaller spot size produces higher energy density for precise cutting, whereas a larger spot size distributes energy over a wider area, making it suitable for broader tissue treatment **[26]**.

Continuous versus pulsed mode:

In continuous mode, laser energy is delivered uninterrupted, making it suitable for rapid tissue cutting and coagulation. In pulsed mode, energy is emitted in short intervals, allowing tissue cooling between pulses, reducing thermal damage and improving precision during delicate clinical procedures **[29]**.

Tissue chromophores (water, haemoglobin, melanin):

Tissue chromophores are naturally occurring molecules that selectively absorb laser energy and determine the clinical response of different laser wavelengths. In dentistry, the principal chromophores are water, haemoglobin and melanin, which influence tissue penetration, cutting efficiency, coagulation and the overall therapeutic effect of laser-assisted procedures **[30].**

Table 1: Summery of wavelengths used in different type of lasers

Laser Type	Wavelength	Primary Tissue Target	Common Clinical Applications
Argon	488–514 nm	Haemoglobin, pigmented tissues	Composite curing, vascular lesions, soft tissue procedures
Diode	800–980 nm (commonly 810, 940, 980 nm)	Melanin, haemoglobin	Soft tissue surgery, periodontal therapy, photobiomodulation
Nd:YAG	1064 nm	Melanin, haemoglobin	Periodontal therapy, microbial reduction, coagulation
Er, Cr:YSGG	2780 nm	Water, hydroxyapatite	Hard and soft tissue surgery, cavity preparation
Er:YAG	2940 nm	Water, hydroxyapatite	Caries removal, bone surgery, cavity preparation
CO_2	10,600 nm	Water	Soft tissue incision, lesion excision, haemostasis

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Clinical applications of lasers in advanced clinical dental practice:

Laser technology has become essential in dentistry because it performs various dental treatments on soft and hard tissues, offering better control and superior precision than traditional techniques. Laser technology has become an integral component of modern dentistry because it enables a wide range of diagnostic and therapeutic procedures involving both soft and hard oral tissues. Its ability to deliver energy with exceptional precision allows clinicians to selectively target diseased tissues while preserving the surrounding healthy structures. Compared with conventional instruments, laser-assisted procedures often provide improved haemostasis, reduced post-operative pain and enhanced patient comfort. In addition, the bactericidal properties of lasers contribute to a cleaner surgical field and a lower risk of post-operative infection. These advantages have expanded the role of laser technology across multiple dental specialties, making it a valuable tool in contemporary clinical practice **[19]**.

Soft tissue surgery:

Lasers in soft tissue surgery can be used in procedures such as gingivectomies, frenectomies, removal of mucosal lesions and gingival tissue remodelling. Soft tissue surgery represents one of the most established and widely accepted applications of laser technology in dentistry. Owing to their ability to precisely incise and coagulate soft tissues simultaneously, lasers provide excellent haemostasis, improved surgical visibility and minimal trauma to adjacent tissues. They are routinely employed for procedures such as gingivectomy, frenectomy, operculectomy, vestibuloplasty, gingival recontouring, crown lengthening and the excision of benign oral lesions. Laser-assisted surgery is associated with reduced intraoperative bleeding, decreased post-operative pain and edema, lower risk of infection due to its antimicrobial properties and, in many cases, a reduced need for sutures. These advantages contribute to faster wound healing, enhanced patient comfort and predictable clinical outcomes, making lasers a valuable alternative to conventional scalpel-based soft tissue surgery **[18].**

Hard tissue surgery:

Lasers are used to remove caries and reshape bone; they are effective on hard tissues like enamel and dentin. Hard tissue lasers have significantly expanded the scope of minimally invasive dentistry by enabling precise procedures involving enamel, dentin and alveolar bone. Er:YAG and Er, Cr:YSGG lasers are the most commonly used systems for hard tissue applications because of their high affinity for water and hydroxyapatite. These lasers are employed for caries removal, cavity preparation, enamel conditioning, bone contouring, osteoplasty and minor osseous surgical procedures. Unlike conventional rotary instruments, laser-assisted hard tissue surgery produces less vibration, noise and mechanical stress, thereby improving patient comfort and reducing anxiety. In addition, the precise ablation of diseased tissue with minimal thermal damage helps preserve healthy tooth structure and promotes favorable healing outcomes following surgical intervention **[28]**.

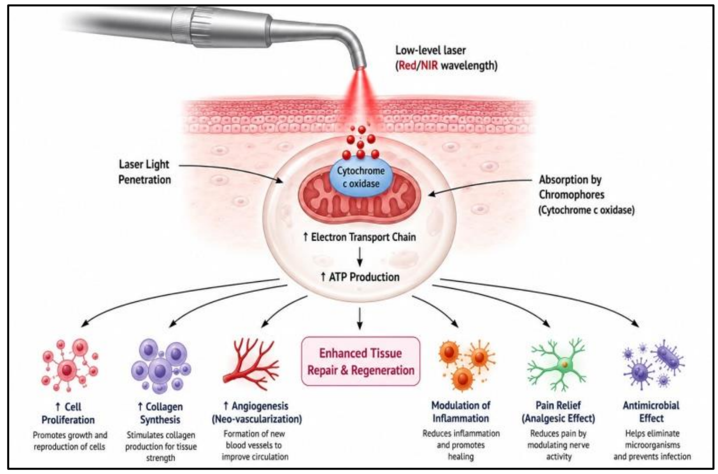

Figure 1: Photobiomodulation (PBM) by Laser

Root canal therapy:

Sterilizing root canals with the laser to eliminate bacteria, improving endodontic treatment **[20]**. Laser technology has emerged as a valuable adjunct in endodontic treatment by enhancing the disinfection of the root canal system beyond the capabilities of conventional irrigation techniques. Owing to their ability to penetrate dentinal tubules, lasers effectively reduce bacterial load, including microorganisms associated with persistent endodontic infections. They are also used to activate irrigating solutions, improve smear layer removal and facilitate debridement of the canal walls, thereby increasing the effectiveness of chemomechanical preparation. Laser-assisted endodontic therapy has been associated with improved canal cleanliness, reduced post-operative discomfort and enhanced periapical healing. Although lasers do not replace conventional instrumentation, their adjunctive use contributes to better microbial control and may improve the overall success of root canal treatment **[29].**

Teeth whitening:

Speeding up the whitening process by activating bleaching agents with the laser. Laser-assisted teeth whitening have become a popular aesthetic dental procedure due to its ability to enhance the effectiveness of conventional bleaching techniques. In this approach, laser energy is used to activate bleaching agents, such as hydrogen peroxide or carbamide peroxide, accelerating the oxidation of chromogenic pigments responsible for tooth discoloration. The activation process shortens treatment time and promotes more rapid and uniform whitening results compared with conventional in-office bleaching methods. Laser-assisted bleaching is particularly effective in managing extrinsic stains caused by dietary habits, tobacco use and aging, as well as selected intrinsic discolorations. The controlled application of laser energy allows efficient activation of the bleaching agent while minimizing unnecessary exposure of surrounding soft tissues. When performed using appropriate clinical protocols, the procedure is considered safe and predictable, with high patient satisfaction. However, careful case selection and adherence to recommended laser parameters are essential to reduce the risk of transient tooth sensitivity or gingival irritation and to achieve optimal aesthetic outcomes **[24].**

Pain management through photobiomodulation:

Low-level laser therapy (LLLT) reduces pain and stimulates tissue after procedures. Low-level laser therapy (LLLT), also known as photobiomodulation therapy, has gained widespread acceptance for the management of pain and the promotion of tissue repair in dentistry. Unlike high-power surgical lasers, LLLT uses low-intensity light to stimulate cellular activity without producing thermal damage. The absorbed light energy enhances mitochondrial function, increases adenosine triphosphate (ATP) production and modulates inflammatory mediators, resulting in accelerated tissue repair and reduced pain perception. In clinical practice, LLLT is commonly used to alleviate post-operative discomfort following oral surgical procedures, reduce inflammation and edema and promote faster wound healing. It has also demonstrated beneficial effects in the management of temporomandibular disorders, dentin hypersensitivity, recurrent aphthous ulcers, oral mucositis and peripheral nerve injuries. The non-invasive nature of the therapy, coupled with its minimal adverse effects, makes it a valuable adjunctive treatment. By enhancing the body's natural healing processes and improving patient comfort, LLLT has become an important component of contemporary dental care and rehabilitation **[22]**. Thus, Pain Management through Photobiomodulation therapy (PBMT) is widely used to reduce pain and accelerate tissue healing by angiogenesis. By stimulating cellular metabolism and modulating inflammatory mediators, PBMT promotes tissue repair while minimizing post-operative discomfort and edema as shown in **Figure 1**. It has proven beneficial in the management of temporomandibular disorders, recurrent aphthous ulcers, oral mucositis, dentin hypersensitivity and peripheral nerve injuries. Its non-invasive nature and minimal adverse effects make photobiomodulation a safe and effective adjunct in contemporary dental practice.

Periodontal treatments:

Laser periodontal treatment to reduce periodontal pockets and stimulate tissue regeneration. Laser technology has become an important adjunct in periodontal therapy by improving the management of periodontal diseases and enhancing treatment outcomes. Various laser systems, including diode, Nd:YAG and Er:YAG lasers, are used for periodontal pocket decontamination, removal of diseased pocket epithelium, gingival curettage and reduction of pathogenic bacterial load. Their antimicrobial properties contribute to effective disinfection of periodontal pockets while minimizing trauma to surrounding healthy tissues. Laser-assisted periodontal therapy has also been shown to promote tissue healing by reducing inflammation, improving blood circulation and stimulating fibroblast activity and collagen formation **[27]**. In addition, lasers have been employed in the management of peri-implant mucositis and peri-implantitis, where they assist in implant surface decontamination and soft tissue healing. Compared with conventional periodontal procedures, laser-assisted treatment is often associated with reduced bleeding, post-operative discomfort and edema, leading to improved patient acceptance. Although lasers are not a substitute for conventional scaling and root planing, they serve as a valuable adjunct in comprehensive periodontal care **[16]**.

Oral lesions and precancerous conditions treatment:

Laser removal of oral lesions and treating precancerous conditions with minimal scarring. Laser technology is widely used for the management of benign oral lesions and selected oral potentially malignant disorders due to its precision and excellent haemostatic properties. It is commonly employed for the excision of fibromas, papillomas, mucoceles, pyogenic granulomas and leukoplakia while preserving the surrounding healthy tissues. Laser-assisted procedures are associated with reduced intraoperative bleeding, minimal post-operative pain, lower risk of infection and limited scar formation, resulting in improved healing, enhanced patient comfort and favorable functional and aesthetic outcomes **[19]**.

Implant dentistry:

Laser technology has become a valuable adjunct in implant dentistry by improving both surgical precision and peri-implant tissue management. It is commonly used for second-stage implant uncovering, soft tissue contouring, decontamination of implant surfaces and the management of peri-implant mucositis and peri-implantitis. The excellent haemostatic and antimicrobial properties of lasers help maintain a clean surgical field while reducing bacterial contamination. Additionally, laser-assisted procedures are associated with reduced post-operative discomfort, minimal bleeding, and faster soft tissue healing and improved patient satisfaction, contributing to predictable implant treatment outcomes **[8].**

Management of oral mucosal diseases:

Laser therapy has showed significant clinical benefits in the management of various oral mucosal diseases by reducing pain, controlling inflammation and promoting tissue healing. It is commonly used as an adjunctive treatment for recurrent aphthous ulcers, oral mucositis, oral lichen planus, herpes labialis and burning mouth syndrome. Owing to its non-invasive nature and biostimulatory effects, laser therapy enhances patient comfort, accelerates mucosal repair and improves overall treatment outcomes with minimal adverse effects **[5].**

Oral and maxillofacial surgery:

Laser technology has significantly advanced oral and maxillofacial surgery by enhancing precision, reducing surgical trauma and improving post-operative recovery. Beyond routine soft tissue procedures, lasers are increasingly utilized in alveoloplasty, bone contouring, and exposure of impacted teeth for orthodontic traction, treatment of peri-implant defects and laser-assisted management of medication-related osteonecrosis

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of the jaws (MRONJ). They also aid in intraoperative haemostasis, surgical field decontamination and post-operative pain control, contributing to improved surgical efficiency and reduced complication rates. In selected maxillofacial procedures, laser-assisted techniques minimize tissue manipulation, decrease edema and post-operative discomfort and facilitate faster functional recovery. Their ability to combine precision with antimicrobial effects has made lasers a valuable adjunct in contemporary oral and maxillofacial surgical practice **[32]**.

Orthodontics:
Lasers have gained increasing applications in orthodontics for procedures such as exposure of impacted teeth, laser-assisted frenectomy, gingival recontouring and operculectomy. They are also used to reduce pain associated with orthodontic tooth movement through photobiomodulation therapy, while promoting faster soft tissue healing, improved patient comfort and enhanced clinical efficiency **[31]**.

Prosthodontics:
Laser technology is increasingly utilized in prosthodontics for soft tissue management before restorative procedures. It is commonly employed for gingival recontouring, crown lengthening, management of hyperplastic tissues and exposure of preparation margins to achieve accurate impressions. Laser-assisted procedures provide excellent haemostasis, minimal post-operative discomfort and improved healing, thereby enhancing the fit, function and esthetics of fixed and removable prosthetic restorations **[11]**.

Oral Diagnosis:
Laser technology has enhanced oral diagnosis by providing non-invasive methods for the early detection and assessment of oral diseases. Techniques such as tissue autofluorescence, fluorescence spectroscopy, optical coherence tomography (OCT) and laser Doppler flowmetry aid in identifying early malignant changes, assessing lesion margins **(Figure 2)** and evaluating pulpal vitality. These diagnostic modalities improve the accuracy of clinical examination, facilitate timely intervention and assist clinicians in treatment planning while reducing the need for invasive diagnostic procedures in selected cases **[12]**.

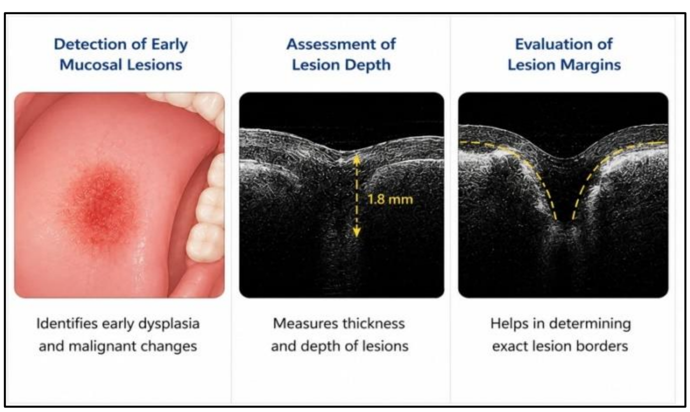

Figure 2: Optical coherence tomography

Oral oncology:
Laser technology plays an important role in oral oncology by facilitating the precise management of selected premalignant and malignant lesions. It is used for photodynamic therapy, laser-assisted excision of early-stage lesions and palliative management of oral cancer–related symptoms. Additionally, photobiomodulation therapy is widely employed to prevent and manage oral mucositis in patients undergoing chemotherapy or radiotherapy, thereby improving comfort and quality of life **[32]**.

Aesthetic dentistry:
Laser technology has transformed aesthetic dentistry by enabling minimally invasive procedures with enhanced precision and predictable clinical outcomes. It is widely used for gingival depigmentation, gingival contouring, crown lengthening, smile design and correction of excessive gingival display to improve overall dental esthetics. Laser-assisted procedures provide excellent haemostasis, minimal post-operative discomfort and rapid soft tissue healing, resulting in improved patient satisfaction and reduced treatment time **[16]**. Furthermore, lasers are increasingly incorporated into multidisciplinary aesthetic treatment planning alongside restorative, periodontal and orthodontic procedures. As advancements in laser technology continue to evolve, their role in aesthetic dentistry is expanding, offering clinicians greater accuracy, improved tissue preservation and more predictable esthetic outcomes while meeting the growing demand for minimally invasive cosmetic dental treatments **[4]**.

Management of salivary gland disorders:
Laser technology has emerged as a valuable adjunct in the management of selected salivary gland disorders by providing a minimally invasive approach with excellent precision and haemostasis. It is commonly used for the excision of mucoceles, treatment of ranulas and management of minor salivary gland lesions while preserving the surrounding healthy tissues. In selected cases, lasers may also assist in the exposure and removal of superficial salivary calculi, improving salivary drainage and gland function. The antimicrobial properties of lasers contribute to a reduced risk of post-operative infection, while minimal tissue trauma results in decreased pain, swelling and scarring. These advantages promote faster healing, improved patient comfort and favorable functional outcomes, making laser-assisted procedures an effective option in contemporary salivary gland management **[6]**.

Treatment of vascular lesions:
Laser therapy is highly effective in the management of vascular anomalies such as haemangiomas, venous malformations and telangiectasias. By selectively targeting haemoglobin within blood vessels, lasers induce controlled photocoagulation while preserving adjacent healthy tissues. This approach minimizes intraoperative bleeding, reduces post-operative complications and provides favorable functional and aesthetic outcomes **[5]**.

Adjunctive antimicrobial applications:

Laser technology has gained considerable importance as an adjunctive antimicrobial modality in advanced dental practice because of its ability to significantly reduce microbial load in infected tissues. Laser irradiation effectively targets bacteria, fungi and certain viruses without extensive damage to the surrounding healthy tissues, thereby enhancing conventional treatment protocols. It is widely used as an adjunct in periodontal therapy, endodontic disinfection, peri-implant disease management and surgical site decontamination. The antimicrobial action of lasers contributes to improved infection control, reduced post-operative complications and enhanced wound healing. Although laser therapy does not replace conventional mechanical debridement or chemotherapeutic agents, its incorporation into routine clinical practice provides an additional level of microbial control and supports more predictable treatment outcomes **[27]**.

Safety considerations in laser dentistry:

The safe use of lasers in dentistry requires strict adherence to established safety protocols to protect both patients and healthcare professionals. Dental lasers are classified according to their potential biological hazards, with Class 3B and Class 4 lasers being the most commonly used in clinical practice. These high-powered systems require appropriate safety measures because of the potential risk of ocular and tissue injury. Protective eyewear designed specifically for the wavelength of the laser in use must be worn by the operator, assistants and patient throughout the procedure. Laser-generated smoke plume may contain particulate matter, microorganisms and toxic by-products; therefore, effective smoke evacuation using high-volume suction and dedicated plume evacuation systems is essential to maintain a safe clinical environment. Since laser energy can ignite combustible materials, careful attention should be given to fire prevention, including avoiding flammable agents, protecting oxygen delivery systems and using laser-resistant instruments when appropriate. In addition, warning signs should be displayed and access to the treatment area should be restricted during laser operation. Comprehensive education and hands-on training are equally important to ensure the correct selection of laser parameters, safe equipment handling and appropriate management of potential complications. Adherence to established laser safety guidelines enhances clinical effectiveness while minimizing risks, thereby promoting the responsible integration of laser technology into contemporary dental practice **[26]**.

Future trends in laser surgery:

As the understanding of tissue laser interaction and the technology are advancing, there is a constant change in the laser surgery and medicine. Knowledge of the current literature and advances in this field is necessary. There are several techniques which are currently being evaluated. Future research should focus on developing affordable materials, improving durability and integrating AI-driven diagnostics to enhance accessibility. Laser dentistry is evolving, with expanded applications beyond periodontics and surgery. Furthermore, ongoing innovations in laser technology are expected to improve treatment precision, clinical efficiency and patient outcomes across a wide range of dental specialties. The development of compact, portable and cost-effective laser systems may facilitate their integration into routine clinical practice, particularly in resource-limited settings. Advances in wavelength optimization and fiber-optic delivery systems are likely to expand the scope of minimally invasive procedures while preserving healthy tissues. In addition, the incorporation of digital workflows, three-dimensional imaging and computer-assisted navigation with laser systems has the potential to enhance treatment planning and surgical accuracy. As robust clinical evidence continues to emerge, standardized treatment protocols and comprehensive training programs will further support the safe and effective implementation of laser-assisted dentistry in modern clinical practice. The present comprehensive review highlights that diode lasers have become a valuable adjunct in oral and maxillofacial surgery, particularly for advanced clinical practice. When compared to traditional methods, evidence from recent clinical studies points to improved haemostasis, decreased post-operative discomfort and improved healing. Positive clinical results are further enhanced by their bactericidal qualities, particularly in procedures that call for a sterile surgical area. However, it is challenging to reach firm conclusions due to study design inconsistency and a lack of long-term data. Even though recent research supports its regular use in certain situations, operator skill and careful case selection are still necessary to get consistent and ideal outcomes.

Advantages:

In advance clinical dental practice, lasers provide a number of clinical benefits that improve patient outcomes and surgical efficiency. Better control during surgery is ensured by laser-assisted treatments, which enable accurate tissue incision with less harm to neighbouring tissues. Because of their innate capacity to coagulate blood vessels, they offer superior haemostasis, which improves surgical field clarity and minimises intraoperative bleeding. Furthermore, lasers have bactericidal qualities that reduce the chance of infection following surgery. Laser-based therapies are a comfortable and efficient substitute for traditional methods since patients frequently experience less discomfort, oedema and scarring, as well as quicker healing and a decreased need for sutures. Additionally, the accuracy of laser application reduces operating time, increasing the effectiveness of treatments in clinical settings. Additionally, better control and visibility lead to more consistent results and increased overall surgical precision. Furthermore, the versatility of laser systems has expanded their applications across multiple dental specialties, including periodontics, endodontics, prosthodontics, implantology, orthodontics and aesthetic dentistry. Their ability to selectively interact with specific tissues enables clinicians to perform minimally invasive procedures while preserving healthy structures and maintaining optimal tissue architecture. Laser-assisted therapy also improves patient acceptance by reducing procedural anxiety associated with conventional rotary instruments, vibration and noise. In many clinical situations, the requirement for local anaesthesia is minimized, thereby enhancing patient comfort and reducing overall chairside time. The excellent decontamination capability of lasers further supports successful treatment outcomes by lowering microbial contamination and promoting a favorable healing environment. In addition, photobiomodulation has emerged as a valuable adjunct for accelerating tissue repair, reducing inflammation and controlling post-operative pain. With continuous technological advancements, improved wavelength specificity and enhanced delivery systems, laser-assisted dentistry continues to evolve as an integral component of advanced clinical practice, offering clinicians greater precision, predictability and efficiency while supporting minimally invasive and patient-centered approaches to oral healthcare.

Limitations:

In oral and maxillofacial practice, lasers have various drawbacks despite their benefits. Their extensive application in regular clinical settings may be limited by the high initial and ongoing costs of the equipment. Additionally, incorrect handling can result in thermal injury to nearby tissues and a poor healing outcome, therefore sufficient training and competence are necessary for optimal use.

Conclusion:

Diode lasers have emerged as valuable tools in advanced clinical dental practice, offering precise tissue management with reduced intraoperative bleeding, enhanced patient comfort and favorable healing outcomes. Growing clinical evidence supports their effectiveness across a wide range of soft tissue procedures. As technology continues to advance, diode lasers are likely to play an increasingly important role in modern surgical dental practice.

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