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Lasers in Oral Medicine: A Review

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Abstract: Lasers have become an integral component of modern oral medicine, transforming both diagnostic and therapeutic approaches through precision, versatility, and minimally invasive techniques. Since their introduction in dentistry, lasers such as CO_2, Nd:YAG, erbium-based, and diode systems have been applied in diverse clinical scenarios including oral mucosal lesions, caries management, periodontal therapy, endodontics, and photobiomodulation. Diagnostic applications like optical coherence tomography and laser-induced fluorescence spectroscopy enhance early detection of malignant and potentially malignant disorders, thereby improving prognosis. Therapeutically, lasers provide superior hemostasis, reduced discomfort, faster healing, and improved esthetic outcomes compared to conventional approaches. Low-level laser therapy (LLLT) has shown remarkable benefits in conditions such as oral lichen planus and mucositis, while advanced modalities support both hard and soft tissue interventions. Despite barriers such as high costs and specialized training requirements, technological advancements particularly in nanotechnology, imaging integration, and AI-guided diagnostics promise broader adoption, consolidating lasers as essential tools in the future of oral healthcare.
Keywords: Lasers, Oral Medicine, Photobiomodulation Therapy, Oral Mucosal Lesions, Optical Coherence Tomography

I. INTRODUCTION

Lasers have emerged as a cornerstone of modern oral medicine, reshaping diagnostic and therapeutic strategies with their precision and versatility. The term LASER an acronym for Light Amplification by Stimulated Emission of Radiation denotes a highly concentrated beam of light capable of interacting with tissues in a selective and controlled manner. Since their first application in dentistry during the 1960s, lasers have steadily advanced, enabling clinicians to perform procedures that are minimally invasive, less painful, and associated with faster recovery times compared to conventional approaches.[1] The clinical utility of lasers in oral medicine spans both diagnosis and treatment. As primary modalities or adjuncts, lasers are applied in managing oral mucosal lesions such as aphthous ulcers, leukoplakia, and lichen planus; facilitating excisional and incisional biopsies; enhancing pain management; assisting in caries detection; and supporting periodontal and peri-implant procedures. Their optical precision allows for targeted tissue ablation while minimizing collateral damage, thus contributing to superior outcomes.[2] Distinct benefits include reduced bleeding during surgery, improved visibility of the operative field, minimal postoperative discomfort, accelerated healing, and decreased reliance on sutures or anesthesia. These attributes not only improve patient comfort but also expand the scope of conservative interventions in oral healthcare.[3]

From a diagnostic standpoint, lasers play a vital role in the early identification of malignant and potentially malignant disorders. Techniques such as laser-induced fluorescence spectroscopy and optical coherence tomography facilitate the detection of oral squamous cell carcinoma at its earliest stages, improving prognosis through timely intervention.[4] Therapeutically, diode and CO_2 lasers are widely employed in soft tissue procedures, while erbium family lasers (Er:YAG, Er,Cr:YSGG) extend their utility to both hard and soft tissue applications, including cavity preparation and osseous surgery.[5] The technological evolution of laser systems has been central to their expanding clinical adoption. Successive generations of devices ranging from CO_2 and Nd:YAG to advanced erbium-based lasers have enhanced precision, efficiency, and safety, broadening the scope of applications in oral medicine practice. Ongoing research continues to refine laser-tissue interactions, expand indications, and optimize patient outcomes.[6]

Despite their advantages, barriers remain to widespread integration. High costs, the necessity for specialized training, and limited evidence in certain fields of dentistry pose challenges to routine adoption. Nonetheless, continuous advancements in laser technology and the growing body of clinical research suggest that their role in oral medicine will only expand, paving the way for more predictable, patient-friendly, and technologically sophisticated dental care.[7] This article gives an overview about lasers in oral medicine.

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II. PRINCIPLES AND MECHANISM OF LASERS IN ORAL MEDICINE

The fundamental principles of lasers in oral medicine are based on the precise and focused delivery of light energy, which interacts with oral tissues for both diagnostic and therapeutic purposes. Unlike conventional light, laser light is highly directional, monochromatic (emitting a single wavelength), and coherent (all light waves are in phase), properties that make it uniquely effective in medical applications. A typical laser system comprises three essential components: an energy source, an active lasing medium (which may be a gas, crystal, or semiconductor), and a pair of mirrors forming an optical cavity that amplifies light through stimulated emission. When laser light reaches biological tissues, its interaction is largely determined by the wavelength of the laser and the optical properties of the target tissue, including absorption and scattering. The primary tissue chromophores that absorb laser energy are water, hemoglobin, and melanin, and the absorption of this energy leads to different biological effects such as heating, ablation, coagulation, or cellular stimulation. Tissue-laser interaction can occur through four main pathways: absorption (the most desired for clinical effect), reflection, transmission, and scattering.[Figure 1] The biological outcome depends on the level of heat generated within the tissue; for instance, temperatures around 60°C cause protein denaturation and coagulation, at 100°C water vaporization occurs resulting in ablation of soft tissues, and above 200°C carbonization and burning may take place, which is generally undesirable. In contrast, low-level laser therapy (LLLT) employs sub-thermal doses of laser energy that do not destroy tissues but instead promote cellular repair, reduce inflammation, accelerate healing, and provide analgesic effects. Various types of lasers have distinct properties making them suitable for different applications in oral medicine: CO_2 lasers are highly absorbed by water and ideal for soft tissue surgery, diode lasers interact effectively with pigmented tissues like hemoglobin and melanin, Nd:YAG lasers penetrate deeply and are often used in periodontal and endodontic procedures, while Er:YAG lasers are strongly absorbed by water and hydroxyapatite, making them effective for both hard and soft tissue treatments. This precise tailoring of laser wavelength and tissue interaction forms the basis for the wide range of clinical applications of lasers in oral diagnosis and therapy, offering minimally invasive, highly effective, and patient-friendly alternatives to conventional techniques.[8]

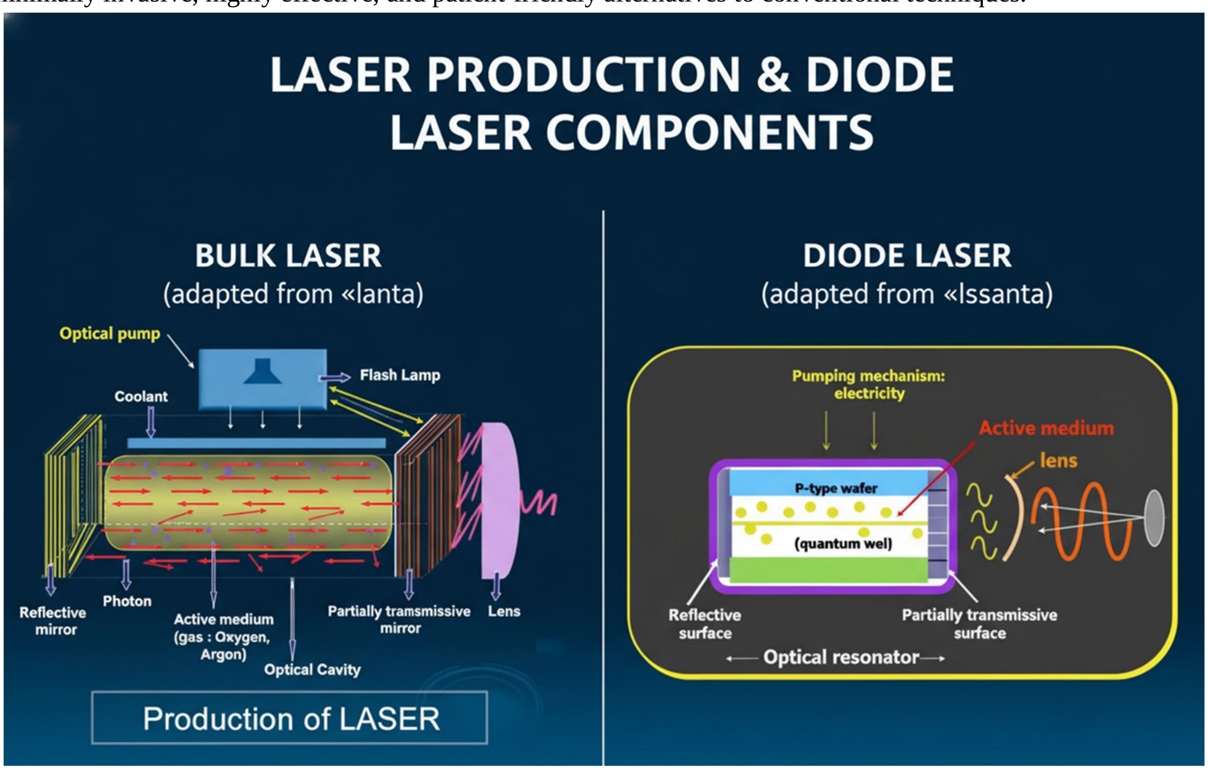

Figure 1: Laser and its components

III. TYPES OF LASERS IN ORAL MEDICINE

The principal lasers employed in oral medicine include CO_2, Nd:YAG, erbium-based (Er:YAG and Er,Cr:YSGG), and diode lasers, each offering unique properties that make them suitable for specific clinical applications. The CO_2 laser, with its strong absorption in water, is highly effective for soft tissue procedures such as incisions, excisions, and ablation, providing rapid cutting, excellent hemostasis, and shallow penetration, though its bulkiness and cost can be limiting factors.[8]

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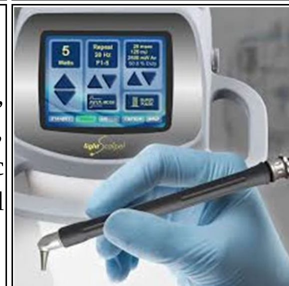
The Nd:YAG laser, operating at a wavelength of 1064 nm, is preferentially absorbed by pigmented tissues like melanin and hemoglobin, allowing for deeper penetration and efficient coagulation, making it particularly valuable in periodontal treatments such as gingivectomy, pocket debridement, and laser-assisted new attachment procedures (LANAP). Erbium lasers, including Er:YAG and Er,Cr:YSGG, have a strong affinity for both water and hydroxyapatite, enabling use in both hard and soft tissue procedures; they are widely applied in cavity preparation, caries removal, osseous surgery, root canal disinfection, and peri-implantitis management due to their dual tissue compatibility.[9] Diode lasers, emitting in the near-infrared range (810–980 nm), are compact, versatile, and primarily absorbed by pigmented tissues, making them highly suitable for soft tissue interventions such as gingival contouring, frenectomies, hypertrophic tissue removal, and bacterial reduction, in addition to their role in photobiomodulation and pain management, though they are not effective on hard tissues. Collectively, these laser systems enhance the precision, safety, and minimally invasive nature of oral healthcare, improving clinical outcomes and patient comfort across a wide spectrum of diagnostic and therapeutic applications.[10]

Types Of Laser	Wavelength / Properties	Primary Tissue Target	Key Clinical Applications	Image
CO_2 Laser	10,600 nm; strong absorption in water; shallow penetration	Water in soft tissues	Soft tissue surgery (incisions, excisions, ablation), leukoplakia excision, gingivectomy, mucosal lesion management, photodynamic therapy; excellent hemostasis, minimal swelling, superior aesthetics	 Figure 2.1
Nd:YAG Laser	1064 nm; absorbed by melanin & hemoglobin; deep penetration	Pigmented tissues (hemoglobin, melanin)	Periodontal therapy (gingivectomy, pocket debridement, LANAP), coagulation and hemostasis, lesion ablation, endodontic disinfection, photodynamic therapy	 Figure 2.2
Er:YAG / Er,Cr:YSGG Lasers	2940 nm (Er:YAG), 2780 nm (Er,Cr:YSGG); absorbed by water & hydroxyapatite	Water & hydroxyapatite	Hard and soft tissue procedures: cavity prep, caries removal, osseous surgery, peri-implantitis management, root canal disinfection, bone and enamel applications	 Figure 2.3

Types Of Laser	Wavelength / Properties	Primary Tissue Target	Key Clinical Applications	Image
Diode Lasers	810–980 nm; compact, portable; absorbed by pigmented tissues	Hemoglobin & melanin (not effective on hard tissue)	Soft tissue surgeries (gingival contouring, frenectomy, hypertrophic tissue removal), photobiomodulation (LLLT for pain & healing), bacterial reduction, mucositis therapy, Fordyce granule removal, aphthous ulcer and herpes management	 Figure 2.4
Excimer Laser (308 nm)	Ultraviolet; superficial penetration	Surface tissues	Lichen planus (erosive form), leukoplakia, mucosal lesions; effective in lesion remission but risk of erythema, soreness, and carcinogenicity	 Figure 2.5
Helium-Neon Laser (632 nm)	Visible red light	Mucosal and submucosal tissues	Low-level laser therapy (LLLT) for oral lichen planus, mucositis, pain reduction, inflammation control	 Figure 2.6
Pulsed Dye Laser	585–595 nm; selective absorption in haemoglobin	Vascular tissues	Photodynamic therapy for leukoplakia, vascular lesion treatment, lesion regression in potentially malignant disorders	 Figure 2.7

IV. LASER THERAPY IN ORAL MUCOSAL DISORDERS

Lasers have gained increasing importance in the management of oral mucosal disorders, particularly for conditions such as lichen planus, leukoplakia, mucositis, and Fordyce granules, where conventional therapies often have limitations. Oral lichen planus, an immune-mediated condition involving T-lymphocytes, presents in keratotic forms that are usually asymptomatic and require no treatment, and non-keratotic erosive forms that necessitate intervention to alleviate symptoms and reduce malignant potential.[11] Traditional management includes corticosteroids, photochemotherapy, and surgery, but low-level laser therapy (LLLT) has emerged as an effective alternative for erosive lichen planus due to its minimal side effects. LLLT produces both primary effects such as vasodilation, enhanced blood flow, lymphatic drainage, fibroblast and neutrophil activation, and increased cellular metabolism and secondary effects involving the aggregation of prostaglandins, immunoglobulins, lymphocytes, and endorphins, collectively reducing pain, inflammation, immune response, and infection.[12]

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Various LLLT modalities, including ultraviolet (below 350 nm), helium-neon (632 nm), and diode lasers (600–1100 nm), have shown efficacy in reducing pain and promoting lesion remission. Clinical studies with 630 nm lasers and 308 nm excimer lasers demonstrated significant pain relief and partial to complete remission in some patients, although UV-B excimer lasers carry risks of erythema, erosion, soreness, and potential carcinogenicity, while red light lasers provide deeper tissue penetration and anti-inflammatory benefits with fewer side effects.[13] Other laser modalities, including diode, Er:YAG, and CO_2 lasers, have also proven effective in reducing lymphoplasmacytic infiltrates and achieving favorable outcomes in biopsy-confirmed lichen planus. Similarly, oral leukoplakia has responded well to CO_2 laser excision, offering minimal pain, swelling, and superior aesthetics, while photodynamic therapy with 5-aminolevulinic acid and pulsed dye lasers has been employed to maintain lesion regression, though recurrence is common if patients continue smoking post-surgery, highlighting the importance of habit modification. In the case of oral mucositis a painful condition that significantly impairs quality of life, particularly in patients undergoing chemotherapy or radiotherapy LLLT has demonstrated remarkable efficacy in reducing pain intensity and accelerating healing of non-keratinized tissues such as the lateral tongue [Figure 3] and floor of the mouth, outperforming conventional therapies like analgesics, anti-inflammatory agents, and biological protectants.[14] Furthermore, Fordyce granule excision using a combination of low- and high-intensity lasers has produced superior esthetic outcomes, faster recovery, and reduced postoperative complications, emphasizing the broad clinical potential of lasers as both therapeutic and supportive modalities in managing diverse oral mucosal lesions.[15]

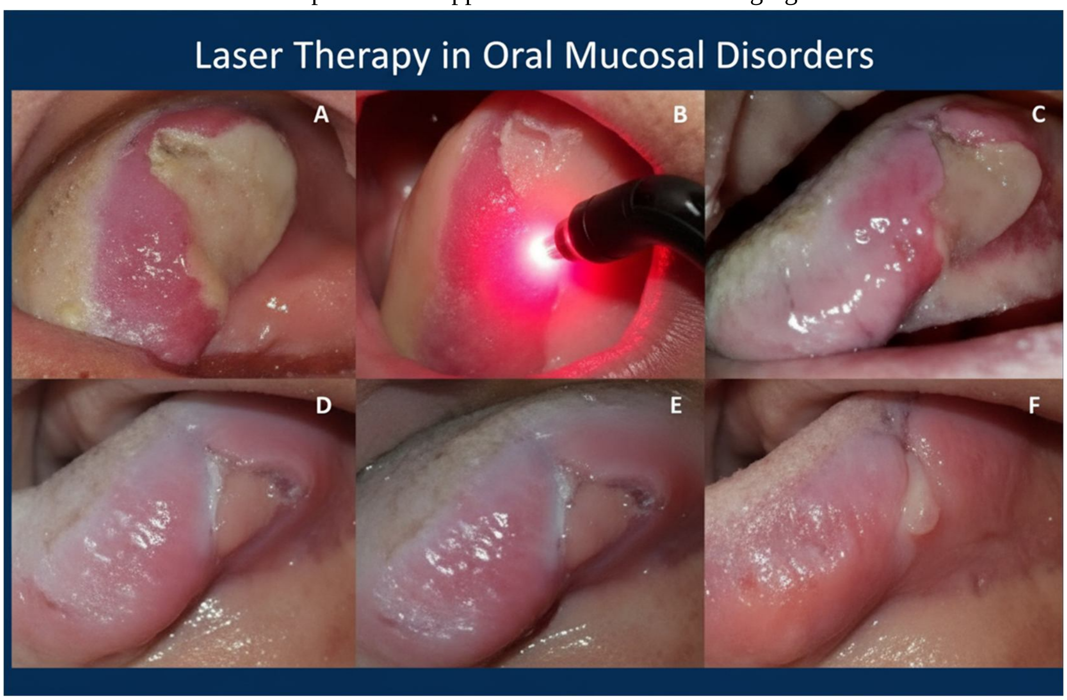

Figure 3: Laser Therapy in Oral Mucosal Disorders [Lymphoma in left lateral surface of the tongue]

V. DIAGNOSTIC APPLICATIONS OF LASERS IN ORAL MEDICINE

The use of lasers in oral medicine has greatly enhanced diagnostic precision, offering minimally invasive alternatives that surpass many conventional techniques. One of the most significant contributions lies in the early detection of oral malignancies, where optical coherence tomography (OCT) enables non-invasive imaging and detailed visualization of oral tissues, while laser-induced fluorescence allows for the identification of malignant and potentially malignant lesions by analyzing fluorescence patterns, both of which improve the chances of early diagnosis and timely intervention. In the detection of dental caries, laser fluorescence devices such as DIAGNOdent [Figure 4] are particularly effective in identifying incipient lesions in occlusal and cervical regions, allowing for earlier preventive care, while photoactivated dye techniques further improve accuracy by enabling both disinfection and selective identification of carious tissues.[16] Additionally, lasers are increasingly used in biopsy procedures, with diode laser biopsies demonstrating advantages over conventional scalpels, including reduced bleeding, improved hemostasis, and lower postoperative discomfort, making them highly suitable for sampling oral soft tissues. Beyond these applications, lasers have also been explored in periodontal diagnostics, assisting in probing depth evaluation and microbial detection, which contribute to more precise periodontal assessments.

Despite their benefits, the adoption of laser-based diagnostics still faces challenges, as many clinicians continue to rely on traditional methods due to familiarity, accessibility, and established protocols; however, with continued technological advancement and professional training, lasers are expected to become integral to routine diagnostic practice in oral medicine.[17]

Figure 4: DIAGNOdent

VI. THERAPEUTIC APPLICATIONS OF LASERS IN ORAL MEDICINE

Lasers have transformed therapeutic approaches in oral medicine by providing minimally invasive solutions for both hard and soft tissue management, offering improved precision, reduced discomfort, and enhanced clinical outcomes. In hard tissue applications, lasers play a significant role in caries prevention by increasing enamel resistance to acid attack and facilitating early lesion detection through laser fluorescence, while also enabling conservative cavity preparation that minimizes the need for traditional drilling methods They are further employed in restorative dentistry for the removal of restorative materials and in procedures where enhanced curing and precision are required. In soft tissue applications, lasers are extensively used in oral surgery for procedures such as excision, frenectomy, gingivectomy, and the treatment of leukoplakia, where they provide excellent hemostasis and improved healing.[18] They are equally valuable in wound management, promoting faster recovery of herpetic and postsurgical lesions, and are increasingly applied in photodynamic therapy, where laser-activated photochemical reactions selectively target malignant tissues Within periodontology, lasers have become integral to procedures such as pocket debridement, bacterial reduction, and photobiomodulation, serving as less invasive alternatives to conventional surgical interventions).[19] Moreover, they are widely applied in endodontics for root canal disinfection and apical surgery, as well as in the management of oral pain and lesions, including aphthous ulcers, herpes simplex infections, and burning mouth syndrome. Additional adjunctive benefits include improved wound healing, effective hemostasis, and reduced postoperative pain, all of which contribute to greater patient comfort and compliance. Despite these advantages, challenges remain, including the potential for thermal tissue damage and the steep learning curve required for safe and effective use, underscoring the need for continuous practitioner training and further research to optimize therapeutic outcomes in oral medicine.[20,21,22]

VII. SAFETY CONSIDERATIONS AND PRECAUTIONS IN DENTAL LASER USE

The integration of laser technology in oral medicine has transformed clinical practice by enhancing precision, minimizing discomfort, and improving treatment outcomes, but its use demands strict adherence to safety protocols to prevent adverse effects. Dental lasers, if misused, can cause significant risks including ocular damage from direct or scattered beams, which makes the use of protective eyewear by both patients and operators mandatory.[23] Accidental tissue injury is another concern, highlighting the importance of controlled application and accurate handpiece positioning to avoid collateral damage. Furthermore, laser procedures may generate hazardous plumes or vapours that can compromise respiratory health, necessitating effective plume management strategies such as high-volume evacuation systems.[24] In addition, the potential fire or explosion hazards associated with certain wavelengths require vigilance and avoidance of flammable materials near the operative field.

To ensure safe practice, adherence to safety classifications and guidelines such as ANSI and IEC standards is critical, alongside rigorous training and certification for practitioners that emphasize laser physics, safety measures, and clinical protocols.[25] Continuous education and operator expertise are therefore indispensable in reducing risks, maintaining tissue safety, and fostering a culture of responsible use. Although lasers provide substantial advantages in oral healthcare, their benefits can only be fully realized through comprehensive precautionary strategies and consistent application of evidence-based safety practices.[26]

VIII. TECHNOLOGICAL ADVANCEMENTS AND FUTURE DIRECTIONS

The continuous evolution of laser technology has significantly broadened its role in oral medicine, advancing both diagnostic and therapeutic applications while paving the way for future innovations. Diagnostic techniques such as optical coherence tomography and laser-induced fluorescence spectroscopy have shown promise in the early detection of oral squamous cell carcinoma, improving diagnostic accuracy and enabling earlier interventions.[27] Therapeutically, lasers are increasingly used for soft tissue procedures including frenectomies, gingivectomies, and lesion ablations, offering clinical benefits such as minimal bleeding, reduced postoperative swelling, and faster wound healing compared to conventional methods. Recent developments in photobiomodulation (PBM) have further enhanced tissue regeneration and inflammation control, supporting improved recovery and patient comfort. Advances in laser engineering, including the introduction of second- and third-generation surgical lasers, novel media, and miniaturized delivery systems, have expanded clinical applications to include photocoagulation, tissue welding, and precision-based restorative procedures.[28] Looking ahead, integration with advanced imaging systems such as fluorescence mapping, coupled with emerging nanotechnology-based laser-activated drug delivery, holds the potential to revolutionize minimally invasive treatments and targeted therapies. Artificial intelligence–guided laser diagnostics are also under exploration, offering the possibility of real-time, chairside decision-making in complex conditions such as oral malignancies. Despite these advances, challenges such as high equipment costs and the need for specialized operator training continue to hinder widespread adoption.[29] Nevertheless, ongoing research and technological refinements are expected to overcome these barriers, positioning lasers as a cornerstone of future dental practice, with applications extending from routine clinical care to minimally invasive oncology.[30]

IX. CONCLUSION

Lasers have revolutionized oral medicine by offering precise, minimally invasive, and patient-friendly diagnostic and therapeutic options. Their applications span from caries management and periodontal therapy to early cancer detection and photobiomodulation. Despite challenges such as high costs and specialized training needs, ongoing innovations in laser technology continue to expand their clinical potential. With integration of AI, nanotechnology, and advanced imaging, lasers are poised to become indispensable tools in the future of dentistry.

X. ABBREVIATIONS

Nd:YAG –Neodymium yttrium garnet
Er:YAG – Erbium yttrium aluminium garnet
Er:Cr:YSGG – Erbium chromium yttrium scandium gallium garnet
LLLT – Low level laser therapy
LANAP – Laser assisted new attachment procedure
OCT – Optical coherence tomography
ANSI- American national standard institute
IEC- Information, Education & Communication or Institutional ethics committee.

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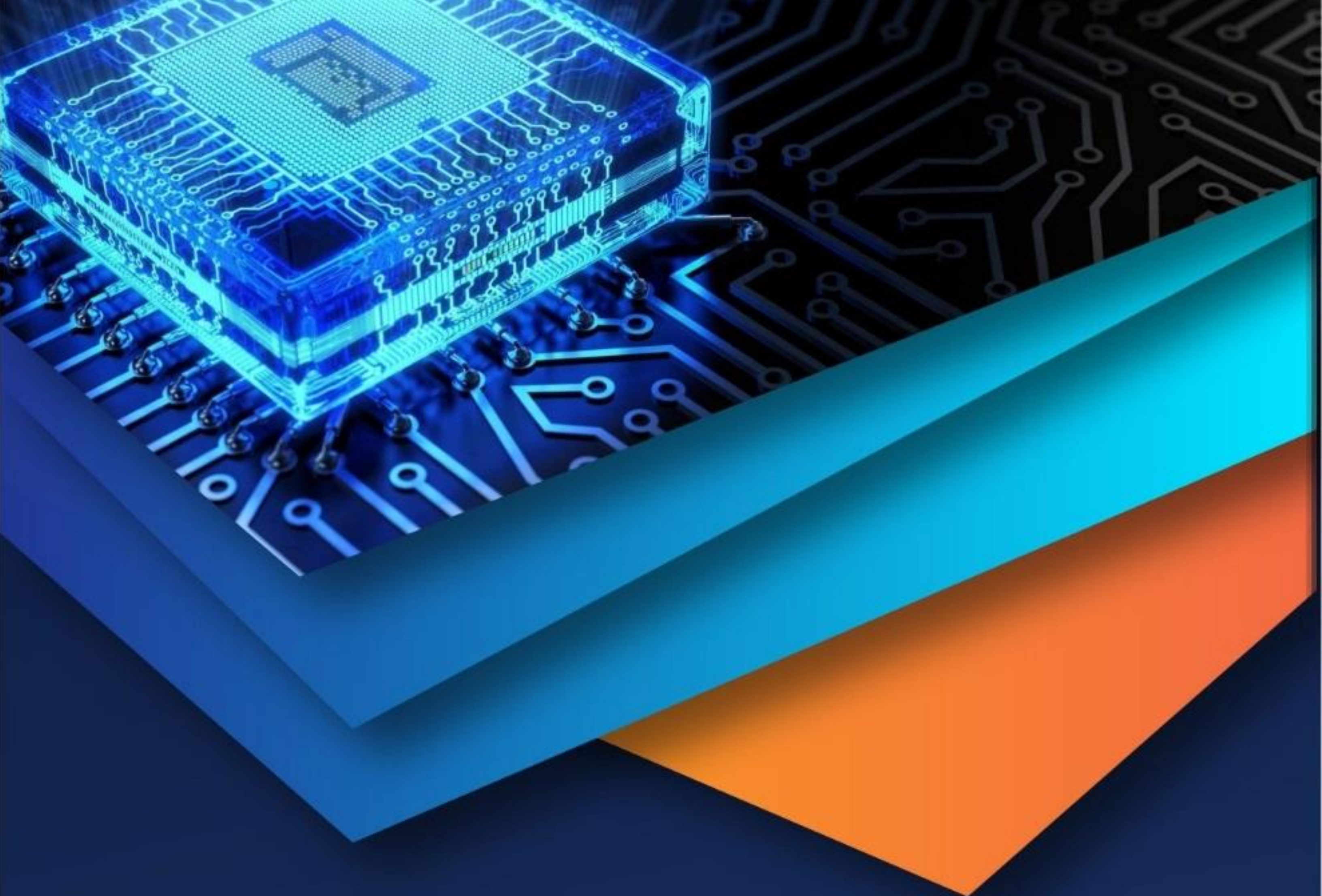

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