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Laser In Prosthetic Dentistry: A Review Article

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Abstract:
Laser dentistry has transformed the field by enabling procedures once reliant on traditional dental tools like drills or scalpels to now be performed with precision and enhanced patient comfort. Formerly, lasers were primarily used for soft tissue procedures, surpassing conventional scalpel surgeries. However, advancements in laser wavelengths have expanded their application to include hard tissue procedures as well. This article explores the diverse applications of laser technology in dentistry, including specialties such as prosthodontics, surgery, periodontics, and endodontics. It delves into the advantages, disadvantages, safety considerations, and applications of lasers in dental laboratories for further research purposes
Materials and Methods*: A search for "laser in prosthodontics" was conducted using the pubmed and google data bases. All the papers referring to this topic, ranging from 2000to 2023, were analysed in the review. This article reviews various application of laser in prosthodontics.*
Results*: From a total of 316000 results, 30 articles met the inclusion criteria and were divided based on their fields of application: complete denture (10). Fixed prosthodontics (10), implantology (10).*
Conclusion: *Laser dentistry offers precise control over treatment parameters, necessitating an understanding of wavelength characteristics and thermal management. Ongoing research promises a bright future for dental lasers, impacting various specialties and improving patient care as technology evolves.*
Key Word: *LASER in Prosthodontics, Fixed Prosthodontics, Implantology.*

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I. Introduction

The term "laser" originates from the acronym "Light Amplification by Stimulated Emission of Radiation" and has found diverse applications across various fields. Over the last century, a series of innovations and breakthroughs have paved the way for the development of laser technology, with each advancement building upon earlier ones[1]. One crucial milestone was the creation of the optical MASER (Microwave Amplification by Stimulated Emission of Radiation) by Charles Townes in September 1957, which laid the foundation for laser technology. In 1957, Gordon Gould, a graduate of Columbia University, coined the term "laser." The first operational laser device, known as the ruby laser, was successfully constructed by Theodore H. Maiman of California on July 7, 1960, following extensive collaborative efforts by numerous scientists[2]. In 1964, Golman et al. and Stern and Sognnaes4 elucidated the impact of the ruby laser on dentin and enamel. Later, in 1985, Myers and Myers adapted an ophthalmic Neodymium-based laser (Nd:YAG) for dental applications.This articles reviews the applications of laser in removable and fixed prosthetic dentistry.

II. Laser Physics

A laser comprises a focused beam of light spanning various wavelengths, characterized by a minimal level of divergence. This light typically falls within the near-infrared (NIR) spectrum[3].

The fundamental principles underlying laser operation can be summarized as follows**:**

1.*Quantum Nature of Light:*

In the realm of quantum mechanics, light exhibits particle-like behaviour with discrete energy levels. Atoms and molecules possess quantized energy levels, and transitions between these levels occur through processes such as absorption, emission, and stimulated emission. These transitions involve the exchange of energy in discrete packets known as photons

2. *Stimulated Emission*

When an electron within an atom or molecule is already in an excited state, it can be further stimulated by the presence of an incoming photon with energy matching the energy difference between its current state and a lower energy level. This stimulation prompts the electron to transition to the lower energy state, releasing a photon in the process. This emitted photon shares the same energy, phase, direction, and polarization as the stimulating photon, leading to amplification of light through a process called stimulated emission. This phenomenon is central to the functioning of lasers, as it enables the generation of coherent and intense beams of light[4].

The fundamental components of a laser include:

1. Optical resonator: This crucial part of a laser comprises two mirrors positioned on opposite ends of the laser medium. One mirror is highly reflective, while the other is partially reflective.
2. Laser gain medium: The active laser medium is responsible for providing optical gain through stimulated emission. This process is initiated by a pump source, which stimulates the gain medium. Examples of materials used for the gain medium include semiconductors like gallium arsenide and gallium nitrate, as well as gas mixtures like helium-neon.
3. Pump Source: Pumping refers to the transfer of energy from an external source to the laser's gain medium. Various pumping methods exist, including optical pumping, electrical pumping, and gas dynamic pumping. These methods serve to excite the gain medium, causing it to emit photons. These photons bounce back and forth between the mirrors in the resonator, amplifying in intensity until they exit through one of the mirrors, resulting in the generation of laser light[5].

III. Lasers In Dentistry

Currently, in modern dentistry, the prevalent laser technologies include Erbium, Nd: YAG (Neodymium Yttrium Aluminium Garnet), diode, and CO2 lasers. Each of these lasers comes with its unique biological implications and operational mechanisms.

The field of dentistry broadly categorizes lasers into three types based on their applications

1. Soft tissue lasers: These lasers are primarily used for procedures involving soft oral tissues, such as gums and mucous membranes
2. Hard tissue lasers: Hard tissue lasers are employed for dental procedures involving hard tissues like teeth and bones, enabling precise and minimally invasive treatments
3. Non-surgical lasers: This category encompasses lasers used for various non-invasive dental procedures, including teeth whitening and pain management, among others[6]

Table 1: Lasers can be categorized based on the lasing medium they utilize[7]

Laser type	Dental application
Excimer lasers 1. Argon fluoride(ARF) 2. Xenon chloride (XeCl)	Hard tissue abrasion Dental calculus removal
Gas lasers 1. Argon (Ar) 2. Helium Neon (He - Ne) 3. Carbon Dioxide (CO2)	Tooth whitening, curing of composite materials, sulcular debridement, intraoral soft tissue surgery Analgesia, dentinal hypersensitivity Intra oral and implant soft tissue surgery, Analgesia
Diode Lasers Indium Gallium Arsenic Phosphorus (InGaArP)	Caries detection
Erbium family of lasers 1. Er: YAG 2. Er: Cr: YSG	Caries removal and cavity preparation Modification of enamel and dentin surface Uncovering of implant, soft tissue surgery
Gallium Aluminium Arsenide	Intra oral and implant soft tissue surgery, sulcular debridement
Solid state lasers 1. Frequency doubled alexandrite 2. Nd: YAG	Selective ablation of dental caries Intra oral soft tissue surgery, sulcular debridement, analgesia

Classification of Lasers

According to the wavelength:

- The *ultraviolet* spectrum range (approximately below 400 nm).
- The *visible* spectrum range (approximately 400-700 nm).
- The *infrared* spectrum range (approximately 700 nm to the microwave spectrum).

Wavelength from ultraviolet to the far infrared range are generally used in medical practice which ranges from 193 nm to 1060 nm[8]

IV. Use Of Laser In Prosthetic Dentistry

Lasers are used and applied in prosthodontics for procedures such as:
In removable prosthesis, their uses include:

- Treatment of enlarged tuberosity
- Surgical treatment of Tori and exostoses
- Treatment of alveolar ridge undercuts
- Unsuitable alveolar ridge treatment
- Soft-tissue lesions.
- Laser welding

Complete denture

- Prototyping & CAD/CAM Technology
- forming of a complete titanium denture base plate
- complete denture study for occlusion using by three - dimensional technique
- Analysis of accuracy of impression by laser scanner

Fixed prosthodontics

- Crown lengthening – soft and hard tissue
- Laser troughing
- Modification of soft tissues around laminates and abutments
- Altered passive eruption management
- Formation of ovate pontic sites
- Removal of veneer
- Crown fractures at the gingival margins[9]

In implantology, their application in various procedures includes:

- For decontamination of socket
- Implant recovery
- Second stage uncovering
- In case of peri - implantitis
- Removal of diseased tissue around the implant
- Sinus lift procedure
- Role of lasers in mini implant placement [10]

Maxillofacial rehabilitation

- Sintering with CAD/CAM technology

Laser applications in the dental laboratory

Complete Denture:

Prototyping & CAD/CAM Technology:

Rapid prototyping (RP) encompasses a range of technologies designed to automatically generate physical models from computer-aided design (CAD) data. Unlike traditional methods reliant on two-dimensional drawings, these technologies, often referred to as "three-dimensional printers," empower designers to swiftly fabricate tangible prototypes of their ideas. Employing an additive process, RP constructs solid objects by sequentially layering materials such as paper, wax, or plastic. This additive approach enables the creation of intricate internal features that would otherwise be unfeasible to produce using conventional techniques.[11]

LASER rapid forming of a complete titanium denture base plate

To produce titanium plates for full dentures, a combination of CAD/CAM and LRF (Laser Rapid Forming) technologies is utilized. Initially, the denture base plate is structured and segmented into numerical control codes through the application of a laser scanner, reverse engineering tools, and the standard triangulation language (STL). Subsequently, the LRF system builds the denture plate layer by layer. Following this manufacturing process, the denture plate undergoes standard finishing procedures to ensure its suitability for use in patients

Study of complete denture occlusion using by three - dimensional technique

By employing a laser scanner alongside three-dimensional reconstruction technology, it becomes possible to assess and explore occlusion following the fabrication of new dentures. This approach facilitates the examination of the interconnectedness of balanced occlusion parameters.[12]

Analysis of accuracy of impression by laser scanner

scanner laser three-dimensional (3D) digitizers are capable of capturing x, y, and z coordinates of surfaces without physical contact. These digitizers have a resolution of 130 mm at 100 mm and record data by detecting points on the surface. Their precise nature allows for accurate estimation of the dimensions of dental impression materials without introducing subjective bias. By constructing images based on distinctive landmarks, these digitizers facilitate the overlay and comparison of two similar images to calculate variations between them.

***Removable Prosthetics**:*

The fabrication of removable full and partial dentures relies heavily on the thorough analysis of the underlying hard and soft tissue structures and their proper preparation before the prosthetic procedure. In recent times, lasers have emerged as valuable tools for various preprosthetic operations, offering advantages in terms of stability, retention, function, and aesthetics. Here's a breakdown of different aspects.

***Reshaping of Alveolar Ridge**:*

Alveolar ridge resorption often leads to a reduction in both vertical and lateral dimensions, necessitating corrective measures. Soft tissue laser surgery utilizing different wavelengths like CO2, diode, and Nd: YAG can effectively flatten the residual ridge, while erbium lasers are suitable for hard tissue surgery.[13]

***Management of Undercut Alveolar Ridges**:*

Undercut alveolar ridges, resulting from dilated tooth sockets or broken alveolar plates, require attention to ensure proper prosthetic fit. Soft tissue lasers are utilized for surgical intervention, while erbium lasers prove beneficial for osseous surgery.

***Treatment of Enlarged Tuberosity**:*

Hyperplastic tuberosity caused by unopposed maxillary molar teeth presents challenges. Laser-assisted torus reduction, particularly with erbium and CO2 lasers, facilitates bone recontouring and minimizes complications like hematoma development.[14]

***Surgical Intervention for Tori and Exostoses**:*

Large or uneven maxillary tori or exostoses can impede prosthetic treatment. Laser technologies such as Ar, XeCl, and Nd: YAG are employed to remove both hard and soft tissues , ensuring proper prosthetic design and alleviating associated discomfort.

Fibroma:

Fibrous tissue can develop due to sharp edges of dentures or excessive pressure on the posterior palatal seal area, leading to persistent tissue injury. Treatment options include soft tissue laser therapy, which promotes tissue re-epithelialization. Carbonized tissue can be effectively removed using a cotton swab soaked in Lotagen® solution (36% dihydroxy dimethyl diphenylmethane-disulfonic polymerized), facilitating rapid and high-quality healing.[15]

Vestibuloplasty:

When poor prosthetic stability is attributed to mandibular or maxillary crest atrophy and reduced vestibule length, vestibuloplasty is recommended. CO2 technology offers a straightforward and secure method without the need for sutures or grafts. Removable dentures should be promptly and temporarily relined with soft acrylic post-surgery, and patients should wear the denture continuously for 3 to 4 weeks.

***Frenectomy**:*

High labial frenulum (median or lateral) can compromise the stability of oral prosthetic structures and necessitates removal to enhance denture retention. A thin layer of soft tissue, at least 1 mm thick, should cover the maxillary bone up to the vestibular end. Sutures are applied exclusively on the lip side of the frenulum, and any insertion of the frenulum at the lip level should be excised.

Epulis Fissuratum:

Epulis, characterized by mucosal overgrowth in patients wearing complete dentures, results from chronic tissue irritation. Common excision techniques include soft tissue laser therapy, surgical scalpel, or electrical scalpel procedures.

Denture Stomatitis:

Denture stomatitis (DS) is a chronic candidal infection prevalent in 60% to 65% of denture wearers. Laser therapy effectively removes superficial candida-contaminated epithelial surfaces and prevents inflammation of adjacent healthy mucosa. Postoperative antibiotics or non-steroidal anti-inflammatory drugs (NSAIDs) are unnecessary as the laser acts as both virucidal and bactericidal, reducing the risk of reinfection or secondary bacterial infections. Additionally, lasers provide significant pain relief through their neuron sealing effect.[16]

Accuracy of Impression and Complete Denture Occlusion:

A newly developed laser scanner functions as a 3D digitizer, tracking specimen coordinates (x,y,z) with a resolution of 130 mm at 100 mm. Complex 3D texture-mapped models are captured by the 3D laser and exported to Scan Surf software, where they are triangulated into a 3D meshwork image of the object.

Denture Fabrication:

Selective laser sintering (SLS) is utilized for denture fabrication. Laser fusion employs a high-power CO2 laser beam to melt polymer or metal powders at elevated temperatures, resulting in the creation of a durable design from a digitized model stored in standard triangulation language (STL) format.

Laser Welding:

Pulsed lasers with low average output power are utilized for repairing defects in removable partial dentures. Effective laser welding requires careful consideration of variables such as pulse energy, pulse length, and peak power, tailored to the specific defect type and stage of the welding process.[17]

In summary, the integration of laser technology in various preprosthetic procedures enhances precision, efficiency, and patient outcomes in removable denture fabrication

***Fixed Prosthodontics**:*

***Crown lengthening**:*

Crown lengthening is a vital procedure aimed at achieving optimal aesthetic and functional outcomes for teeth exhibiting various conditions such as caries at the gingival margin, cuspal fractures extending below the gum line, inadequate clinical crown length, challenges in determining the finish line placement, or when aesthetic enhancement is desired. Soft tissue lasers, including those from the erbium family, are commonly utilized for such procedures, with erbium lasers particularly suited for osseous recontouring. Following surgery, it is advisable to provisionally restore the area and allow for a 3-4 week healing period before taking a final impression

***Laser troughing**:*

Laser troughing presents an innovative approach to creating a trough around teeth prior to impression-taking, eliminating the need for retraction cords, electrocautery, or haemostatic drugs. This method offers predictable outcomes, efficiency, and time savings by minimizing epithelial attachment impingement, reducing bleeding during subsequent impressions, and mitigating postoperative complications. It also modifies the biological width of the gingiva, typically employing Nd:YAG lasers.[18]

***Soft tissue modification**:*

Soft tissue modification around laminates and abutments can be efficiently accomplished using argon lasers, allowing for swift and effective removal and recontouring of gingival tissue. These lasers serve as primary surgical tools for addressing both diseased and non-diseased gingival tissue resulting from medication therapy or orthodontic treatment. Argon lasers provide tissue removal, hemostasis, and promote tissue reattachment to the wound, facilitating procedures such as gingivoplasty

Management of altered passive eruption :

Management of altered passive eruption can be effectively addressed using lasers, particularly in cases involving uneven margins. Laser technology enables the precise removal and recontouring of soft tissues, such as gingival margins, with minimal complications, ultimately enhancing aesthetic outcomes

Ovate pontic :

Formation of ovate pontic sites, essential for achieving aesthetically pleasing and hygienic pontic designs, may require soft and bony tissue recontouring. Various soft tissue lasers are suitable for such procedures, while erbium lasers are preferred for osseous surgery. These techniques contribute to creating optimal conditions for successful pontic placement and long-term oral health.[19]

Veneer Removal Technique:

A method for veneer removal involves the utilization of laser energy. This energy penetrates through the porcelain glass of the veneer without affecting it, instead being absorbed by water molecules present at the adhesive interface. As a result, debonding occurs between the silane and resin components, facilitating the removal process without causing harm to the underlying tooth structure. Specifically, lasers like Er, Cr: YSGG are employed for the precise removal of unwanted or failed veneers[20]

Addressing Crown Fractures Near the Gum Line:

In cases of crown fractures occurring near the gingival margins, Er: YAG or Er, Cr: YSGG lasers can be strategically employed. These lasers are carefully maneuvered to provide optimal exposure of the fracture margin, aiding in the accurate assessment and subsequent treatment.

Bleaching:

In-office bleaching procedures often utilize Ar and diode lasers. Notably, the KTP laser combined with H2O2 gel (Smart Bleach gel [SBI]) represents the sole laser bleaching system known for its photothermal, photochemical, and photocatalytic capabilities. Laser tooth whitening aims to achieve maximum bleaching efficacy while minimizing adverse effects.

Laser photodynamic therapy before impression taking

Ensuring an accurate impression is vital for the effectiveness and precision of prosthetic restorations. Swollen and inflamed gingival tissue can impede the dryness of the prosthetic area and affect the precision of subsequent impressions. Laser photodynamic therapy emerges as a novel approach for periodontal pre-prosthetic preparation. This therapy not only promotes effective healing but also offers bio-stimulation and regenerative benefits. By selectively targeting damaged tissues and pathogens, the dye used in photodynamic therapy minimizes harm to healthy tissues.[21]

Dentinal decontamination:

High-level laser therapy (HLLT) is employed as the final step prior to crown cementation, owing to its superior ability to penetrate dentinal tissues and its microbial inhibitory properties.[22]

Implantology:

Implantology encompasses several procedures aimed at ensuring successful dental implants.

Socket decontamination:

One crucial aspect is socket decontamination, especially after tooth extraction. Erbium and CO2 lasers offer efficient decontamination by eliminating soft tissue residues and sterilizing bone surfaces without causing significant damage.[23]

Implant site recovery

It can be expedited and facilitated with laser technology. By utilizing lasers, the implant can be exposed and impressions obtained simultaneously. Laser surgery minimizes tissue shrinking, resulting in level tissue borders after healing, while also reducing damage to surrounding tissues

Second stage recovering:

During the second stage uncovering, various laser wavelengths can be employed except for Nd: YAG due to its adverse effects on dental implants. CO2 lasers are particularly effective for removing thick soft tissue, ensuring clear visibility of the surgical site

For treating mucositis and peri-implantitis:

For treating mucositis and peri-implantitis, lasers provide a newer and more effective approach. Erbium, CO2, or diode lasers can be utilized for this purpose. CO2 lasers can effectively cleanse implant sites by melting microorganisms in deep bone lesions, thus preventing complications.[24]

a) Laser technology also aids in the removal of diseased tissue around implants, sterilizing their surfaces and eliminating inflammation. Diode, CO_2, and Er: YAG lasers are commonly employed for this purpose, ensuring optimal implant health[25]
b) ***In sinus lift procedures****:* lasers offer advantages such as reduced risk of sinus membrane puncture and decreased postoperative pain and edema. Yttriumscandium-galium-garnet (YSGG) lasers are particularly useful for avoiding sinus membrane damage and making precise osteotomies during bone grafting.[26]
c) Additionally, lasers play a role in mini implant placement, facilitating gentle penetration into soft cancellous bone. Laser sterilization of bone surfaces can enhance the success of mini implants by creating a clean osteotomy site, potentially leading to improved outcomes.

Use of laser as a hemostatic tool:

A significant number of patients undergoing implant procedures are on long-term anticoagulant therapy or have other systemic medical conditions, necessitating swift and effective hemostasis. Hence, the potential of laser usage in achieving better stabilization of blood clots at the surgical site is under evaluation.

In a study conducted by Ackermann, Nd:YAG laser application with a handpiece was found to be effective in achieving hemostasis. Based on the principles of laser-tissue interactions and hemoglobin absorption of laser wavelengths, Nd:YAG and diode lasers are considered to offer the most effective hemostatic outcomes, followed by CO_2 lasers, while the effectiveness is relatively lower for Er:YAG and Er,Cr:YSGG lasers.[27]

Regarding tooth extraction in patients with bleeding disorders, studies have demonstrated the effectiveness of bare fiber diode or Nd:YAG lasers in controlling bleeding. Horch and Deppe conducted a clinical study involving 44 patients where the bare laser technique, along with pulsed laser to minimize thermal effects, was employed. The study concluded that intra-alveolar application of pulsed Nd:YAG laser energy can be deemed safe.

Table 2: Effect of laser in implantology [28]

Study	Laser wavelength	Type Of Study	Effects
Kato et al	CO2	IN VITRO	Bacterial reduction
Bach et al	Diode (810nm)	Clinical	Pocket reduction
Romanos et al	Nd:YAG	In vitro	Significant melting
Romanoset al	CO2	Clinical	Periimplantitis therapy
Arnabat-Dominguez et al	Er:YAG	In vivo	Second stage surgery
Schwarz et al	Er:YAG	In vitro	Reduction in bleeding On probing
El Montaser et al	Er:YAG	In vivo	No thermal damage
Kesler et al	Er:YAG	In vivo	Better osseointegration
Lewandowski et al	Er:YAG	In vivo	Better healing than The drill
Schwarz et al	Er:YAG	In vivo	Safe (but not better) Healing compared With the control
Deppe et al	CO2	Clinical	Periimplantitis therapy
Dorbtbudak et al	Photodynamic Therapy	In vitro	Bacteria reduction

Maxillofacial Rehabilitation

The utilization of Laser Holography Imaging presents a valuable method for gathering detailed information regarding a patient's deformity through the utilization of laser surface digitizing tools

Innovations in CAD/CAM technology have revolutionized the production of facial prostheses, offering significant advantages over traditional methods. One such breakthrough involves employing selective laser sintering technology to create wax templates for maxillofacial prostheses, providing an efficient alternative that minimizes labor-intensive processes.[29]

The application of lasers in dental laboratories has shown promising results, particularly in enhancing bond strength between titanium castings and porcelain compared to conventional acid etching methods. Beyond this, lasers find utility in various areas such as welding, prototyping, CAD/CAM technology development, occlusion analysis, impression accuracy measurement via laser scanning, and sintering titanium components for prosthetic devices.

V. Laser Safety And Medico-Legal Considerations

Classification by International Electrotechnical Commission (IEC), indicate the level of laser beam hazard[30]

TABLE 3: Classification by International Electrotechnical Commission (IEC), indicate the level of laser beam hazard

CLASS	DESCRIPTION
I	Very low risk. Non-harmful producing laser
IM	Safe except when seen through magnifying optics. Wavelength between 302.5 nm and 4000 nm.
II	Do not authorized human admittance to contact levels beyond the Class 2 AEL (Accessible Emission Limit) for wavelength between 400 nm and 700 nm. No known risk with 0.25 seconds (aversion response).
IIM	Hazardous when viewed through an optical instrument. Wavelength between 400 nm and 700 nm. No known harm with 0.25 seconds (aversion response) unless collecting optics are used.
IIIR	Safe with restricted beam viewing.Wavelength between 302.5 nm and 160 nm.
IIIB	Direct viewing is harmfull to the eyes. Normally safe if viewing diffuse reflections
IV	Serious injury potential to eye and skin. Harmful effect under both intra beam and scater reflection seeing situations cause a fire hazards.

VI. Conclusion

The integration of lasers in dentistry and prosthodontics has notably enhanced the efficacy of prosthetic procedures, facilitating patients in restoring both function and aesthetics. Through precise control over power output and exposure duration, laser technology has revolutionized dental treatments by enabling dentists to target specific areas with minimal risk of collateral damage to surrounding tissues. As laser-based interventions gain traction among patients, they foster a deeper bond between dentists and their clientele, leading to a more collaborative approach to oral healthcare

Ethical Considerations:
Not applicable.

Conflict of Interests:
None.

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