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Overview and Perspective on Fixed Prosthodontic with Laser Technology

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نظرة عامة ومنظور حول تركيبات الأسنان الثابتة باستخدام تقنية الليزر

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Abstract:
Laser, an acronym for Light Amplification by Stimulated Emission of Radiation, represents a sophisticated and versatile technology with broad applications in contemporary dental practice. This modality generates a monochromatic, coherent beam of light through photon-induced chain reactions, enabling precision in both diagnostic and therapeutic interventions. Commonly utilized dental lasers include diode, argon, Er,Cr:YSGG, Er:YAG, Nd:YAG, and carbon dioxide (CO_2) systems. Due to their distinctive physical and biological properties, these devices can be effectively applied to both soft and hard tissues, with parameters tailored to various clinical contexts. In comparison to conventional techniques, laser-based approaches offer several clinical advantages, including enhanced hemostasis, reduced intraoperative bleeding, minimal postoperative discomfort, and accelerated tissue healing. Within the domain of fixed prosthodontics, concerned with the restoration of function, esthetics, and oral physiology, lasers have demonstrated substantial utility. This review aims to delineate the specific applications of laser technology in fixed prosthodontics, emphasizing its impact on procedural efficiency and patient outcomes. A focused discussion on intraoral laser interventions underscores their role in optimizing gingival management, esthetic refinement, and prosthetic integration. The integration of laser systems into fixed prosthodontic procedures heralds a transformative approach to managing oral tissues, offering numerous benefits such as reduced operative time, minimized discomfort, and improved precision. However, improper use may result in deleterious tissue effects, necessitating that clinicians possess a solid understanding of laser physics, laser-tissue interaction dynamics, and appropriate clinical protocols. As laser technologies continue to evolve, their incorporation into routine dental practice is anticipated to become indispensable, significantly advancing the quality and predictability of prosthodontic treatments.

Keywords: Lasers; Fixed Prosthesis; Gingival Troughing; Esthetics; Crown Lengthening; Soft Tissue Management; Veneer Removal; Ovate Pontic.

الملخص
الليزر، وهو اختصار لعبارة "تضخيم الضوء بالانبعاث المحفز للإشعاع (Light Amplification by Stimulated Emission of Radiation "، يُمثّل تقنية متقدمة ومتعددة الاستخدامات ذات تطبيقات واسعة في ممارسات طب الأسنان المعاصر. تنتج هذه التقنية شعاعًا ضوئيًا أحادي اللون ومتناسقًا عبر تفاعلات متسلسلة ناجمة عن الفوتونات، مما يتيح دقة عالية في كل من التشخيص والعلاج. تشمل أنواع الليزر المستخدمة شيوعًا في طب الأسنان: ليزر الديود، الأرجون،

Er,Cr:YSGG، Er:YAG، Nd:YAG، وأنظمة ثاني أكسيد الكربون (CO_2). وبفضل خصائصها الفيزيائية والبيولوجية المميزة، يمكن تطبيق هذه الأجهزة بفعالية على الأنسجة الرخوة والصلبة على حد سواء، مع إمكانية ضبط معايير التشغيل بما يتناسب مع مختلف السياقات السريرية. وعند مقارنتها بالتقنيات التقليدية، توفر الأساليب المعتمدة على الليزر عدة مزايا سريرية، بما في ذلك تحسين التحكم في النزيف، تقليل النزيف أثناء الجراحة، تقليل الانزعاج بعد العملية، وتسريع التئام الأنسجة. وفي مجال التعويضات السنية الثابتة، المعني بإعادة الوظيفة، والجمالية، والفسيولوجيا الفموية، أثبت الليزر فاعلية كبيرة. تهدف هذه المراجعة إلى توضيح التطبيقات المحددة لتقنية الليزر في تعويضات الأسنان الثابتة، مع التركيز على تأثيرها في تحسين كفاءة الإجراءات السريرية ونتائجها على المرضى. وتُبرز المناقشة المركزة حول تدخلات الليزر داخل الفم دورها في تحسين إدارة اللثة، وتعزيز النتائج الجمالية، وتكامل التركيبات السنية. إن دمج أنظمة الليزر في إجراءات التعويضات الثابتة يُمثّل نهجًا تحويليًا لإدارة الأنسجة الفموية، حيث يقدم العديد من الفوائد مثل تقليل وقت العمل الجراحي، وتخفيف الإزعاج، وتحسين الدقة. ومع ذلك، قد يؤدي الاستخدام غير الصحيح إلى آثار سلبية على الأنسجة، مما يستدعي من الممارسين امتلاك فهم راسخ لفيزياء الليزر، وديناميكيات تفاعل الليزر مع الأنسجة، وبروتوكولات الممارسة السريرية السليمة. ومع استمرار تطور تقنيات الليزر، من المتوقع أن تصبح جزءًا لا غنى عنه في الممارسة اليومية لطب الأسنان، مما يعزز بشكل كبير جودة وتوقعات نتائج علاجات التعويضات السنية.

الكلمات المفتاحية: الليزر؛ التعويضات الثابتة؛ حفر اللثة؛ الجماليات؛ إطالة التاج؛ إدارة الأنسجة الرخوة؛ إزالة الفينير؛ الجسر بيضاوي النهاية.

Introduction:

Since its inception in 1960, laser technology has been progressively integrated into both medical and dental disciplines. Over subsequent decades, the scope and sophistication of laser applications in dentistry have expanded significantly, offering solutions to limitations associated with conventional techniques [1,2]. Today, lasers are employed across nearly all dental specialties, including oral medicine, oral and maxillofacial surgery, pediatric dentistry, restorative dentistry, endodontics, periodontics, implantology, and prosthodontics, demonstrating their versatility and clinical efficacy [3,4].

In the field of fixed prosthodontics, numerous studies and clinical reports have emphasized that the incorporation of laser systems contributes to enhanced procedural precision, improved treatment efficiency, and favorable prognostic outcomes. Both clinicians and patients benefit from these innovations, which promote superior hemostasis, accelerated wound healing, and minimal postoperative discomfort [5]. Consequently, laser-assisted interventions are associated with minimally invasive, highly controlled, and patient-centered treatment protocols.

Dental lasers are categorized according to several criteria, including wavelength, active medium, mode of emission, delivery system, absorption characteristics, and clinical application. Based on wavelength, lasers are classified into three primary spectral ranges: ultraviolet (UV, 140–400 nm), visible spectrum (VS, 400–700 nm), and infrared (IR, >700 nm), with IR lasers being the most commonly used in clinical dentistry. Depending on the active medium, laser types include gas lasers (e.g., argon, CO_2), solid-state lasers (e.g., Nd:YAG, Er:YAG), semiconductor lasers (diode lasers), and dye lasers. Delivery systems vary among articulated arms, hollow waveguides, and fiber-optic cables [6-8]. Furthermore, lasers may operate in optically or electrically pumped emission modes, adding another layer of classification based on their physical and technical configuration.

Among the most commonly utilized lasers in dentistry are:

- Carbon Dioxide (CO_2) Lasers: Operating in the infrared range (primarily at 10,600 nm), these are optimal for soft tissue applications due to their strong absorption by water-containing tissues. Clinical applications include gingivectomy, frenectomy, and crown lengthening. Additionally, a CO_2 laser variant with a wavelength of 9300 nm can be used effectively for hard tissue ablation [9-10].
- Diode Lasers: First introduced in the late 1990s, diode lasers emit in the near-infrared spectrum (typically 810–980 nm) [11-14]. They are highly favored for their portability, cost-effectiveness, and efficacy in soft tissue management. Clinical advantages include minimized bleeding, reduced edema, improved surgical field visibility, and minimal or no requirement for suturing, contributing to decreased postoperative morbidity.
- Erbium Family Lasers (Er:YAG and Er,Cr:YSGG): These lasers, operating at wavelengths of 2940 nm (Er:YAG) and 2780 nm (Er,Cr:YSGG), are particularly effective for hard tissue applications due to their affinity for water and hydroxyapatite. They are known for their capacity to ablate tissue without generating heat, sound, or vibration, thus enhancing patient comfort and reducing the psychological burden associated with traditional rotary instrumentation [15-18].

Given this diversity, the judicious selection of laser type and parameters is essential for ensuring optimal clinical outcomes. In prosthodontics, effective soft tissue management is foundational for achieving esthetic and functional success, making lasers a valuable adjunct to treatment protocols. Figure 1 shows Sequential stages of laser-assisted tooth preparation showing cavity access, selective tissue removal, and final preparation margins for prosthetic restoration.

Figure 1: Sequential stages of laser-assisted tooth preparation showing cavity access, selective tissue removal, and final preparation margins for prosthetic restoration.

A topic of ongoing debate in the literature is the use of lasers for crown preparation. Although empirical data remain limited, emerging technologies, particularly Er,Cr:YSGG lasers with fiber-optic tips, have been proposed as viable alternatives to conventional rotary instruments. These systems utilize hydrokinetic laser energy to ablate both soft and hard tissues, often without the need for local anesthesia. The precision afforded by these systems may reduce operative time and enhance patient comfort. Furthermore, the Er:YAG laser has shown promise in tooth preparation, offering anesthetic effects while minimizing the risk of enamel microfractures, a concern associated with high-speed handpieces. However, successful clinical implementation of such techniques requires advanced training and a thorough understanding of laser-tissue interactions.

Gingival Troughing Formation

Accurate impression-taking is a fundamental prerequisite in the fabrication of fixed dental prostheses, necessitating precise recording of both the prepared abutment and the gingival finish line. To achieve this, gingival retraction is essential, particularly when the finish line is located subgingivally. Gingival retraction is defined as the temporary lateral displacement of the gingival margin to expose the cervical portion of the tooth [19-21]. Conventional retraction techniques, mechanical (e.g., retraction cords), chemomechanical, and surgical methods (e.g., electrosurgery, rotary curettage), are often technique-sensitive and may cause discomfort or trauma. In contrast, laser-assisted gingival troughing offers a minimally invasive, hemostatic alternative, enabling superior visualization of the margins, reducing chair time, and minimizing patient discomfort. Furthermore, lasers promote coagulation by sealing blood vessels and decrease the reliance on chemical hemostatic agents, enhancing procedural predictability.

Soft Tissue Management

Soft tissue manipulation is integral to achieving optimal esthetic and functional outcomes in fixed prosthodontics. Procedures such as crown lengthening, gingivectomy, and gingivoplasty involve the excision and recontouring of gingival tissues surrounding abutments and veneers. These interventions aim to harmonize gingival contours, correct excessive gingival display (e.g., “gummy smile”), and prepare the peri-abutment tissue for ideal prosthetic emergence profiles [22-24]. While botulinum toxin injections have traditionally been employed to manage gummy smiles by modulating upper lip elevation, recent comparative studies indicate that diode or erbium lasers yield more immediate, stable, and longer-lasting esthetic results without the need for repeated treatments.

Crown Lengthening

Traditionally performed with scalpels and rotary instruments, crown lengthening can now be effectively executed using erbium lasers, particularly Er,Cr:YSGG at 2780 nm. Clinical studies comparing conventional and laser-assisted crown lengthening demonstrate that although both techniques initially increase crown exposure, laser-treated sites maintain a stable gingival margin over time. In contrast, surgically treated sites often exhibit relapse due to marginal tissue recession [25-27]. Additional benefits of laser-based surgery include superior hemostasis, reduced postoperative edema, fewer mechanical injuries, and expedited healing. These advantages contribute significantly to enhanced workflow, particularly in facilitating subsequent impression-taking and prosthesis fabrication.

Ovate Pontic Site Preparation

In anterior fixed partial dentures, the ovate pontic design offers exceptional esthetic outcomes due to its ability to simulate natural tooth emergence profiles. However, the success of this approach hinges on adequate hard and soft tissue architecture. Traditionally, shaping of the recipient site required long-term provisionalization or invasive methods such as electrosurgery or rotary instruments [28-30]. Currently, diode lasers offer a refined technique for site preparation, providing sterile operating fields, precise soft tissue contouring, hemostasis, and reduced postoperative morbidity. This laser-based approach can often be completed during the initial visit, streamlining treatment timelines and improving patient satisfaction.

Tooth Surface Decontamination

Surface decontamination prior to cementation is a critical step in optimizing the longevity and success of fixed prosthetic restorations. High-energy Er,Cr:YSGG lasers can be used for effective decontamination without compromising tooth structure, while low-level diode lasers provide biocidal effects suitable for use on crowns seated on implants [31-33]. Importantly, diode lasers can sterilize surfaces such as zirconia and porcelain without altering their microstructure, thereby preventing biofilm formation and reducing the risk of peri-implantitis and secondary caries.

Tooth Surface Conditioning

Surface conditioning enhances the adhesion between the tooth substrate and luting agents. Historically, techniques such as acid etching with hydrofluoric acid have been used to create microporosities for mechanical retention. Laser conditioning, particularly with the Er:YAG laser, offers a modern alternative by inducing enamel recrystallization and micro-roughening, thus promoting similar retention with reduced risk of enamel damage. However, potential drawbacks include thermal effects and the formation of micro-cracks. Research by Labunet et al. evaluated the efficacy of various lasers (Er:YAG, Er,Cr:YSGG, Nd:YAG, and CO_2), concluding that Er:YAG offers optimal results due to its efficiency and conservativeness on hard tissues [34-36]. For ceramics such as zirconia, laser microstructuring has been shown to enhance bonding through the formation of consistent parallel grooves, improving the Weibull modulus and material reliability while maintaining flexural strength.

Removal of Ceramic Restorations

The removal of defective or unsatisfactory ceramic restorations poses a significant clinical challenge when performed using conventional mechanical techniques, which often require anesthesia and risk iatrogenic damage. Laser-assisted debonding, particularly with erbium or CO_2 lasers, facilitates selective ablation of the resin cement layer through thermal degradation, allowing for safer, faster, and more precise removal of ceramic restorations without compromising underlying structures [37-39].

3D Printing and Digital Workflow Integration

Laser sintering technologies such as Selective Laser Sintering (SLS) and Selective Laser Melting (SLM) have revolutionized the digital workflow in prosthetic dentistry. These additive manufacturing techniques enable the production of high-precision metal frameworks for metal-ceramic restorations by selectively fusing powdered metal layers based on CAD designs. This method eliminates the limitations of conventional casting,such as marginal misfit, porosity, and material inconsistencies, and ensures superior adaptation and mechanical integrity of the prosthesis. The process involves layer-by-layer deposition of metal powders (20–150 µm thick), followed by targeted laser irradiation using galvanometric scanning systems, thereby achieving optimal geometry and fit [40-42].

Smile Design and Periodontal Aesthetics

Laser technology has also been incorporated into digital smile design workflows to sculpt soft tissue contours with precision. Prior to laser application, gingival outlines are demarcated using reference lines based on axial inclination and zenith points. A periodontal probe is utilized to determine the biological width, which is then marked with laser energy to maintain a functionally and aesthetically optimal gingival margin [43-46]. This technique allows clinicians to achieve symmetry, contour harmony, and a well-defined visual endpoint for prosthetic placement.

Advantages and Disadvantages

Advantages

The utilization of laser technology in fixed prosthodontics offers numerous clinical advantages, positioning it as one of the most conservative and patient-centered treatment modalities. Among the key benefits is its minimally invasive approach, whereby laser systems selectively target specific tissues while preserving adjacent anatomical structures. This precision results in reduced intraoperative trauma, thereby enhancing procedural outcomes and patient comfort.

Laser-assisted interventions also contribute to accelerated healing and reduced postoperative discomfort. The mechanism of action, sealing of nerve endings, hemostasis through vessel coagulation, and minimal collateral tissue damage, significantly reduces bleeding, edema, and pain, facilitating a more comfortable and efficient recovery process. Furthermore, the hemostatic and antimicrobial properties of lasers promote blood clotting during soft tissue procedures and aid in the decontamination of operative fields, thereby decreasing the risk of postoperative infection and enhancing the long-term success of prosthodontic restorations.

Disadvantages

Despite these advantages, laser applications in fixed prosthodontics are not without limitations. A primary barrier to optimal clinical outcomes is the limited knowledge and insufficient training among practitioners. Effective and safe laser use necessitates comprehensive understanding of laser-tissue interactions, the technical specifications of various laser systems (e.g., wavelength, power settings, emission mode), and adherence to established safety protocols. Without such foundational knowledge, the risk of iatrogenic complications, such as thermal injury to soft and hard tissues, increases substantially.

Moreover, while lasers hold promise in procedures such as ovate pontic site preparation, robust clinical evidence supporting their efficacy in specific prosthodontic applications remains limited. The current body of literature lacks large-scale, evidence-based trials to validate many of these procedures definitively. Finally, financial considerations pose a substantial limitation, as the acquisition and maintenance of laser equipment involve significant capital investment, potentially limiting accessibility, particularly in resource-constrained settings.

Future Perspectives

Historically, the adoption of lasers in dentistry has been constrained to researchers and specialists, primarily due to high costs and concerns related to thermal control and safety. However, technological advancements are expected to transform this landscape. In the near future, it is anticipated that more refined, cost-effective, and user-friendly laser systems will be developed, featuring optimized pulse modulation, reduced energy output, and enhanced precision, thereby minimizing invasiveness and improving treatment predictability.

In addition, the integration of laser technology with CAD/CAM systems will expand the scope of digital prosthetic dentistry. Coupled with artificial intelligence (AI)-driven treatment planning, lasers may facilitate highly individualized and accurate prosthodontic interventions, improve workflow efficiency, and standardize clinical protocols. AI can assist clinicians in determining optimal laser settings based on specific procedural requirements, enhancing treatment outcomes while ensuring patient safety. The convergence of laser systems with advanced digital technologies heralds a future in which laser-assisted prosthodontics becomes a cornerstone of routine dental care.

Conclusion

The application of laser technology in modern dentistry, and specifically in fixed prosthodontics, has ushered in a paradigm shift in the management of both soft and hard oral tissues. Lasers offer numerous clinical advantages, including reduced procedural time, diminished patient discomfort, improved hemostasis, and accelerated healing, factors that collectively enhance the quality of care and clinical efficiency. However, the successful integration of lasers into prosthodontic practice necessitates comprehensive clinician education, adherence to evidence-based protocols, and prudent selection of laser systems tailored to specific clinical scenarios.

Although the technology presents significant promise, its widespread adoption is currently limited by gaps in clinical training, financial constraints, and the need for further empirical validation. Nevertheless, the ongoing evolution of laser technology, especially its potential synergy with digital and AI-based platforms, strongly indicates that lasers will become an indispensable tool in future dental practice, advancing both the science and art of prosthodontics.

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