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Exploring the Role of Laser Technology in Dentistry: A Concise Overview

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ABSTRACT
The realm of dentistry is characterized by continuous advancement, perpetually seeking superior materials, techniques, and innovations. Laser technology has emerged as a significant answer to many of these quests since its pioneering introduction by Maiman in the 1960s. Over time, lasers have become integral in various dental procedures, including caries removal, cavity preparations, treatment of dental hypersensitivity, etching, composite polymerization, teeth whitening, canal sterilization, as well as soft tissue and apical surgeries. This literature review aims to provide a succinct exploration of the diverse applications of lasers in dentistry.

I. INTRODUCTION

LASER, an acronym for light amplification by stimulated emission of radiation, represents a transformative technology in dentistry.3 Operating as heat-generating devices, lasers convert electromagnetic energy into thermal energy, offering a unique blend of high power and beam quality unmatched by traditional light sources.4 Since its emergence in the 1960s, laser technology has become increasingly integrated into dental procedures.5 Unlike in other medical fields, in dentistry, lasers serve as adjuncts, facilitating precise tissue management for both hard and soft tissue procedures.6 This literature review seeks to provide a concise overview of the multifaceted applications of lasers in dentistry.[1,2,3,4]

HISTORY

The term LASER was initially introduced to the public sphere in 1959 by Gordon Gould, a graduate student at Columbia University. Subsequent advancements in laser technology led to notable milestones: in 1961, the development of a laser generated from yttrium-aluminum-garnet crystals treated with neodymium (Nd: YAG); in 1962, the creation of the argon laser; and in 1963, the ruby laser's pioneering use in medical applications, particularly for coagulating retinal lesions. Another significant development occurred in 1964 when the CO2 laser was developed by Patel at Bell Laboratories. Presently, diode lasers have emerged as prominent tools extensively utilized in the field of dentistry.[5, 6]

PRINCIPLE OF LASER

Laser action operates on the fundamental principles of the quantum nature of light and stimulated emission. Through this process, lasers generate heat, transforming electromagnetic energy into thermal energy. The emitted laser possesses three distinctive characteristics: it is monochromatic, coherent, and collimated.[7, 8, 9]

TYPES OF LASER

Dental lasers are categorized based on the active medium they utilize. This medium can take various forms, including liquids (such as dye) or gases (e.g., argon and carbon dioxide), solid-state crystal rods like neodymium: YAG (Nd:YAG) and Erbium:YAG (Er:YAG), or semiconductors, as seen in diode lasers. [10]

CLINICAL APPLICATION OF LASER IN DENTISTRY

Laser technology is poised to revolutionize dentistry, offering significant advancements in clinical applications. Its ability to treat both hard and soft tissues without direct contact, vibrations, or pain makes it a versatile tool applicable across various branches of dentistry.

LASER AS A DIAGNOSTIC TOOL

Argon and diode lasers are commonly employed for detecting and quantifying dental caries through methods such as Diagnodent. Additionally, diode lasers are utilized for subgingival calculus detection and for assessing pulpal blood flow via Laser Doppler Flowmetry. Helium-neon lasers play a role in scanning phosphor plates of digital radiographs. Nd:YAG and Er:YAG lasers are utilized for spectroscopic analysis and confocal cytometric imaging of both soft and hard tissues. These laser technologies offer diverse applications in dental diagnostics, enhancing precision and efficiency in oral health assessments. [11]

LASER APPLICATION IN CONSERVATIVE DENTISTRY

Numerous in vitro and initial in vivo studies have demonstrated that argon laser irradiation offers a degree of protection against enamel caries initiation and progression. Various delivery systems for argon lasers have yielded similar results, indicating effectiveness in reducing caries susceptibility of both sound enamel and white spot lesions. Recent in vitro research has shown reductions in lesion depth on primary tooth surfaces through argon laser irradiation combined with topical acidulated phosphate fluoride treatment (APF). Additionally, the CO2 laser has been utilized for caries prevention, with investigations indicating its beneficial effect on enamel acid resistance.[12, 13, 14, 15]

In caries removal, the higher water content of carious material compared to surrounding healthy dental hard tissues results in greater ablation efficiency. The Er:YAG laser shows promise in selectively removing carious material due to its differing energy requirements for ablation, leaving healthy tissues minimally affected.[16]

The (Er,Cr:YSGG) laser has been explored as an alternative to acid etching for enamel and dentin surfaces. Laser-etched enamel and dentin surfaces exhibit micro-irregularities and the absence of a smear layer. However, it's noted that adhesion to dental hard tissues following Er:YAG laser etching is generally inferior to that achieved through conventional acid etching methods.[17, 18, 19]

LASER APPLICATION IN SURGERY

Diode lasers have emerged as a transformative solution for traditional gingival surgeries, offering a less painful alternative with reduced discomfort and bleeding. Additionally, patients undergoing laser procedures experience rapid healing with minimal scarring. [19]

A frenum is a fold of mucous membrane that connects the cheek or lips to the alveolar mucosa, gingiva, and underlying periosteum. Abnormalities in the frenum can lead to various issues such as midline diastema, trauma, and poor oral hygiene. Surgical removal of the frenum, known as frenectomy, may be necessary in such cases. Laser technology has emerged as an effective surgical tool for frenectomy, offering several advantages including a bloodless field, clear and simple technique, absence of sutures, and excellent postsurgical healing of the tissue. The Erbium laser is commonly used for frenectomy procedures, often with simultaneous water spray to enhance precision and minimize thermal damage. Frequencies of 30–40 Hz are typically employed during Erbium laser frenectomies. [20, 21]

The pulsed Nd:YAG laser is extensively utilized for analgesia in endodontics. Its wavelengths interact with the sodium pump mechanism, leading to changes in cell membrane permeability. This alteration temporarily affects the sensory neuron endings, consequently blocking the depolarization of C and A fibers of the nerves.[22]
Conservative tissue removal can be employed to expose an impacted or partially erupted tooth for bonding, facilitating the placement of a bracket or button. This approach offers several advantages, including minimal bleeding, immediate attachment placement, and a pain-free experience for the patient.[19]

LASER IN ORAL APHTHOUS STOMATITIS

Oral aphthous stomatitis is known for its painful oral ulcers and frequent recurrence. Low-level laser treatment has emerged as a highly effective intervention, providing immediate pain relief and subsequent reduction in ulcer size. A study utilizing the diode laser demonstrated remarkable improvement when applied at a power of less than 1 megawatt and a wavelength of 810 nm. [23, 24]

LASER APPLICATION IN PEDODONTICS

Lasers have been increasingly utilized for pulpotomy procedures in primary teeth due to their ability to maintain a sterile environment and reduce inflammation. Shoji et al. first applied lasers for pulpotomy procedures in dog's teeth, noting no detectable damage in the remaining pulp tissue. In addition to their sterile and anti-inflammatory properties, lasers possess hemostatic, antimicrobial, and cell-stimulating properties. They offer the added advantages of improved wound healing and no mechanical damage to the remaining pulp tissue. Consequently, laser irradiation has been suggested as a promising alternative to conventional pharmacotherapeutic strategies.[25]

Lasers are valuable for achieving hemostasis and cavity disinfection during pulp capping and amputation procedures. In a study by Yazdanfar et al. (2015), diode lasers were employed during pulp capping, demonstrating greater effectiveness compared to conventional methods. Similarly, the erbium chromium laser has shown promising results in this regard. Additionally, lasers can be utilized to reduce dentin permeability in teeth with no pulp exposure, as demonstrated in research by Stabholz et al. (2004). [26 27]

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LASER IN ORTHODONTICS

In orthodontic practice, lasers offer a range of common applications, including accelerating tooth movement, remodeling bone, enamel etching before bonding, and debonding ceramic brackets. They also aid in pain reduction post-orthodontic force application and prevent enamel demineralization. Soft-tissue procedures like frenectomies, gingival contouring, and crown lengthening are also effectively performed using dental lasers.[28]

Lasers have proven efficient in both acid etching and debonding of brackets, resulting in a decrease in the adhesive remnant index and minimal increase in pulp temperature. Particularly, Nd:YAG and CO2 lasers have shown satisfying results with minimal side effects on pulp temperature.[29]

Furthermore, lasers facilitate soft tissue manipulation, such as exposing teeth in submucosal inclusion for disimpaction and distal gingival resection for mandibular molar eruption. These procedures are rapid and yield almost bloodless fields.

In addition, lasers are utilized for joining metal frameworks, utilizing YAG crystals with neodymium. Laser welding offers advantages such as no solder, preventing corrosion at the joint, smaller focus, and an argon shielding atmosphere that prevents oxidation around the welding zone.[29]

LASER SAFETY

While dental lasers are generally user-friendly, it's crucial to observe certain precautions to ensure their safe and effective use. Firstly, wearing protective eyewear designed for specific wavelengths is paramount for everyone in the vicinity of the laser, including the operator, patient, assistant, and any nearby family members. Precautions against accidental exposure include placing warning signs on doors, minimizing reflective surfaces, restricting access to the surgical environment, and ensuring the laser is in good working condition. Additionally, adequate ventilation is essential to allow the escape of vapors during tissue ablation, which may be harmful to individuals present in the surgical room. These precautions help to maintain a safe environment for both patients and dental professionals during laser procedures.[11]

II. CONCLUSION

Laser-based technology holds significant promise for the future of dentistry, emphasizing the integration of diagnostic and therapeutic laser techniques. In recent decades, the use of lasers across all dental specialties has experienced dramatic growth. Ongoing research continues to demonstrate the numerous benefits of laser therapy, leading dental professionals to increasingly accept them as viable alternatives to traditional therapies. This trend reflects the growing recognition of lasers' versatility, precision, and effectiveness in various dental procedures, paving the way for enhanced patient care and treatment outcomes.

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