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Applications of Light Amplification by Stimulated Emission of Radiation (Lasers) for Restorative Dentistry

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Key Words

Ablation · Caries detection · Computer-assisted design and manufacturing · Tooth

Abstract

Light amplification by stimulated emission of radiation (laser) has been used widely in a range of biomedical and dental applications in recent years. In the field of restorative dentistry, various kinds of lasers have been developed for diagnostic (e.g. caries detection) and operative applications (e.g. tooth ablation, cavity preparation, restorations, bleaching). The main benefits for laser applications are patient comfort, pain relief and better results for specific applications. Major concerns for using dental lasers frequently are high cost, need for specialized training and sensitivity of the technique, thereby compromising its usefulness particularly in developing countries. The main aim of this paper is to evaluate and summarize the applications of lasers in restorative dentistry, including a comparison of the applications of lasers for major restorative dental procedures and conventional clinical approaches. A remarkable increase in the use of lasers for dental application is expected in the near future.

Introduction

Restorative dentistry involves several procedures aimed at restoring the tooth or tooth tissues, exemplified by the diagnosis and extension of caries (tooth decay) and its management. For conventional restorative dentistry, ablation of teeth is carried out using either high- or low-speed rotary hand-held pieces to remove carious tooth structure and for crown preparation [1]. Resin composites need to be polymerized to form a flowable plastic mass to a solid restoration. Other restorative dentistry procedures include extrinsic teeth stains using bleaching agents, endodontic treatments and indirect restorations manufactured in the dental laboratory [2]. However, all of these procedures take a lot of time and can be very stressful to the patients [3]. Furthermore, toxic issues may be involved when chemicals are used such as formocresol, a material commonly used for devitalization of dental pulp that may damage liver and kidney tissues [4]. To overcome these disadvantages of the conventional procedures, light amplification by stimulated emission of radiation (laser) has become an attractive alternative that led to a recent evaluation of the efficacy and feasibility of using lasers in dentistry [5–10].

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Table 1. Key events in the development of lasers

Author(s)	Year	Achievement	Source
Newton	1704	Characterized light as a course of particles	[11]
Young's interference	1803	Polarity of light was discovered convincing other scientists that light was discharged in the mode of waves	[11]
Maxwell	1880	Postulated electromagnetic (EM) theory of light and described wave-like nature of electromagnetic field; concluded light is an EM wave	[11]
Plank	1900	Black body radiation theory; described EM radiations released using a black body and thermal equilibrium at a specific temperature	[11]
Albert Einstein	1917	Proposed the theory of wavelength	[11]
Rudolf Ladenburg	1926	Studied negative dispersion of gaseous neon using an electric current	[18]
Valintin Fabrikant	1939	Proposed the usage of stimulated emission to amplify short waves	[18]
Lamb and Retherford	1947	Discovered stimulated emission in hydrogen spectra	[19]
Charles Townes	1953	Invented first-ever microwave amplification by the stimulated emission of radiation (MASER)	[11]
Gordon Gould	1956	Discovered that optical pumping could be used to excite a MASER	[20]
Townes and Schawlow	1957	Conducted extensive research on infrared and visible light laser	[20]
Alexander Prokhorov	1957	Proposed the use of ruby as a medium to produce LASER	[20]
Theodore Maiman	1960	Invented the first LASER; used ruby as an active medium	[11]
Javan et al.	1960	Invented the first gas laser	[21]
Nikolay Basov	1961	Conducted research on semiconductors and high-frequency lasers	[18]
Robert N. Hall	1962	Invented and used the first laser diode laser	[18]
Nick Holonyak Jr.	1962	Used the first semiconductor laser producing a visible emission	[18]
ZhoresAlferov, Izuo Hayashi & Morton Panish	1970	Devised room-temperature, continual-operation diode lasers, using the heterojunction interface of crystals	[18]

For production of a laser, a high-intensity light is produced when a medium is provided with electric energy and a light source (which can be an arc lamp or another laser). The resultant light can be focused using a lens or a grating to produce a laser beam. Based on spontaneous and stimulated emission of radiation, the fundamentals of lasers were developed by Albert Einstein in 1917 [11]. Although the effect of lasers on extracted teeth were first studied during 1960s [12], it was not until 1989 that the first commercially available dental laser was used clinically to ablate enamel and dentin [13]. Eventually, lasers were employed in the field of dentistry for a variety of applications. In addition to ablation of dental hard tissues [9], lasers had also been used for oral soft tissue applications including surgery [14], surgical tool in periodontal therapy [15], and in the field of endodontics and implantology [16]. Furthermore, recent advances in 3D laser scanning and computer-assisted design and manufacturing (CAD/CAM) technology has made production of 'digital impressions' possible [17]. The key steps in the development of laser technology are summarized in table 1. The aim of this review was to evaluate and summarize the use of lasers in restorative dentistry and assess their current status in clinical restorative dentistry.

Basic Principle

A laser beam discharges photons in the form of a focused, coherent and monochromatic energy ray that interacts with a target tissue such as dental material. When a laser interacts with oral tissues, there are four possible outcomes: transmission, reflection, scatter and/or absorption as illustrated in figure 1. Cutting of soft tissues and ablation of hard tissues is dependent upon the 'absorbance' of light by the targeted tissues [11]. Transmission occurs when there is no interaction between the tissues and the laser. When transmitted, due to the difference in the refractive indices of air and the tissue, some light is refracted [22]. Reflection is a possible outcome of a laser-tissue interaction in which the laser beam is deflected back instead of being absorbed. Scatter occurs when long wavelength lasers such as carbon di-

Table 2. Commonly used types of lasers for dental applications

Laser type	Wavelength, nm	Applications	Power/energy output	Fluence, J/cm^2	Ref.
Near-UV	600	Bleaching	600–2,000 mW	0.5	[24]
Diode	635, 670, 810, 830, 980	Diagnosing caries	<1 mW	N/A	
Nd:YAG	1,064	Soft tissue ablation, etching of teeth	4,050 mW	24	[25, 26]
Nd:VO$_4$ (USPL)	355, 532, 1,045, 1,064	Ablation of tooth/restorative materials	7,000–18,000 mW	1.3–11.4	[27]
Er,Cr:YSGG	2,780	Tooth ablation, CAD/CAM, pulpotomy, etching	5,000 mW	15	[28, 29]
Er:YAG	2,940	Tooth ablation, CAD/CAM, etching	500–1,000 J	24 (CAD-CAM), 203.7 (ablation)	[30, 31]
CO$_2$	9,600, 10,600	Soft tissue ablation, etching, caries inhibition	25–320 W	5–20	[32]

oxide (CO$_2$) and neodymium-doped yttrium aluminum garnet (Nd:YAG) pass through the oral tissues in multiple directions. This phenomenon is particularly important when dealing with the effects of lasers on the tissues (e.g. absorbance, scattering) surrounding the target area. Absorption occurs when the majority of the light beam is converted to heat, called photopyrolysis, which can permanently alter the structure of the protein in the tissue. Furthermore, photovaporolysis, evaporation of tissues, can also be caused by absorption. Photoplasmolysis occurs when the tissues absorb the laser beam and 'explode' due to the rapid expansion caused by heat. Absorptive effects in restorative dentistry are important because of the ability of the incident laser beam to photovaporize dentin and enamel. Photoplasmolysis is primarily useful in soft tissue laser surgery whereas ablation of teeth mainly involves photovaporolysis [11].

Type of Dental Lasers

There is a wide range of lasers available for applications in dentistry which can be classified according to different criteria [23], such as medium used and intended applications. CO$_2$, Nd:YAG, erbium-doped yttrium aluminum garnet (Er:YAG), erbium/chromium-doped yttrium aluminum garnet (Er,Cr:YSGG), diode and neodymium:vandate (Nd:VO$_4$) are the most commonly used materials as media to produce lasers for use in dentistry. Nd:YAG and CO$_2$ lasers are used for cutting soft tissues, while Er:YAG and Er,Cr:YSGG along with CO$_2$ lasers are used for cutting mineralized dental hard tissues [23]. Commonly used lasers and required specification for various dental applications are mentioned in table 2, while those that can be used to cut oral soft and hard tissues are shown in figure 2. For ablation of hard tissues, high-powered lasers are used because they interact with the target tissues directly. However, soft lasers achieve required tissue interaction indirectly through an increase in blood circulation and warming tissue that leads to therapeutic effect or ablation at higher powers.

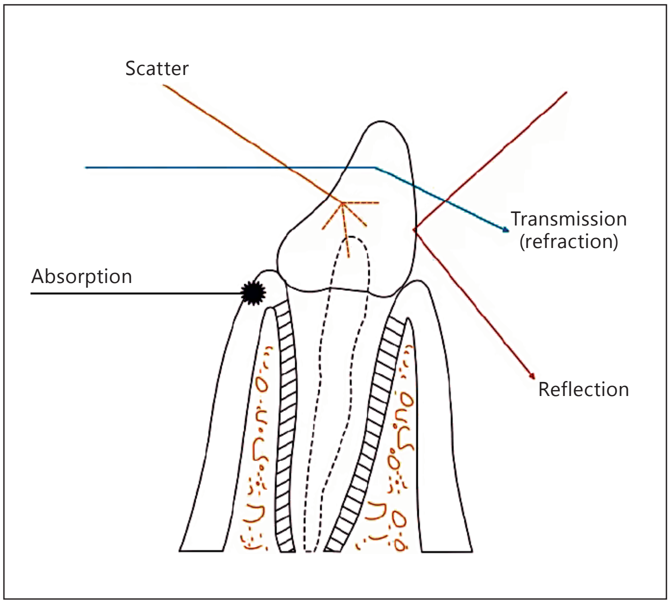

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Fig. 1. Resultant possible outcomes of laser and dental tissue interaction; presentation of transmission, reflection, scatter and absorption phenomenon.

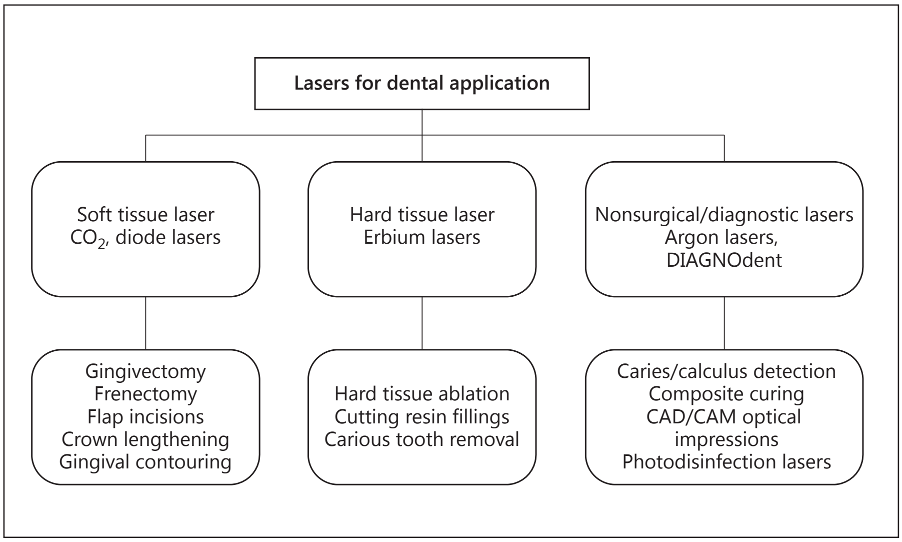

Fig. 2. Types of dental lasers based on major clinical applications [17].

Applications in Restorative Dentistry

Laser technology is being used for a wide range of applications in restorative dentistry (fig. 3). The key applications of lasers are discussed below.

Diagnostic Applications for Caries Detection

Conventionally, caries (tooth decay) diagnosis is made using a good visual examination, explorers and radiography, but such diagnosis of caries is not always straightforward [33]. Certain factors such as complex tooth structure/morphology, saliva, bacterial plaque and food particles may restrain the visibility and many carious lesions may remain undetected. To overcome these shortcomings, laser devices such as DIAGNOdent and DIAGNOcam (fig. 4a, b) have been introduced. DIAGNOdent is the most widely used laser-fluorescence caries detection device. It uses a red laser (wavelength ~688 nm) based on the principle that healthy (nonpathological mineralized) and carious enamel and dentin tooth tissues have different fluorescent properties that are detected by the device. As such, it has demonstrated acceptable levels of reproducibility of diagnosis [34] of caries and is recommended as an adjunct diagnostic tool along with conventional radiography. An in vitro study that compared the diagnostic capabilities of DIAGNOdent and radiographs suggests that laser-assisted caries diagnosis is significantly more effective than radiographs in detecting occlusal caries [35]. DIAGNOdent use alone increases the chances of 'false positives' [36], hence it is highly recommended that it should be used along with radiography for a more accurate caries diagnosis [37]. However, the latest technologies such as quantitative light-induced fluorescence [38] and VistaProof [39] have claimed to be more efficient in detecting early and incipient carious lesions. In addition, these devices have the added advantage of producing a visual diagnosis that can be shown to the patients and thereby involve them in treatment planning.

Removal of Carious Tooth Structure

The treatment of dental caries involves removal of carious and healthy tooth tissues via high- and low-speed air turbine hand pieces in addition to manual excavators in order to prepare the tooth for subsequent restoration. Teeth are composed of extremely hard enamel (hardness: 1.24–5.75 GPa) and dentin (hardness: 0.55–0.91 GPa). Both tissues are anisotropic in nature [40, 41]. Hence, in addition to heat that can cause pulpal damage, rotary instruments produce sound and vibrations which can be causes of discomfort for patients. To overcome these drawbacks, lasers capable of ablating mineralized tissues, such as CO_2 and erbium lasers, are used for tooth tissue ablation without noise and vibrations. However, laser ablation can cause production of excessive heat which can be deleterious to pulpal tissues. It has been observed that uncooled laser ablation of enamel can lead to a temperature rise as high as 300–800 °C that may lead to permanent damage to the dental pulp [42]. In dentistry, such temperature rise is minimized by means of a high-flow water spray [43]. Water, having a high specific heat ca-

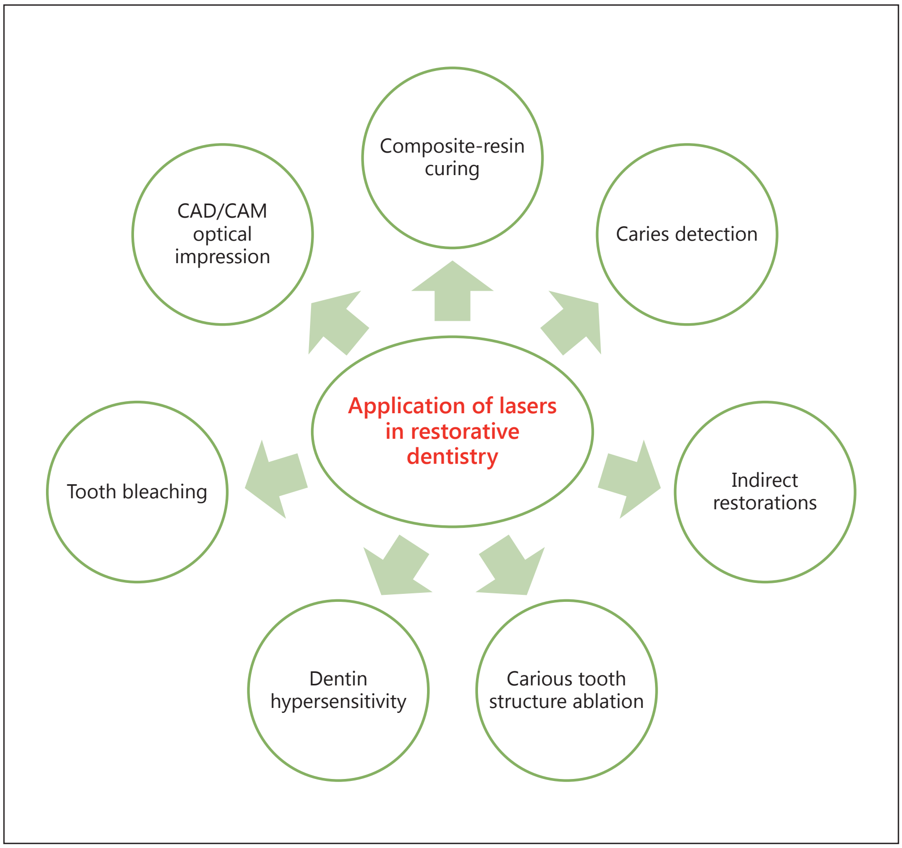

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Fig. 3. Clinical applications of lasers for restorative dentistry procedures.

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Fig. 4. Dental laser devices. **a** DIAGNOdent pen used for caries detection directly in the oral cavity. **b** DIAGNOcam used for caries detection directly in the oral cavity. **c** A modern laser unit (Biolase) used for soft and hard oral tissues cutting; various accessory attachments and settings can be used depending on the requirement of the clinical procedure.

pacity, absorbs the heat and evaporates to cool down the site of cavity preparation. Recent studies [44, 45] have described that although lasers of higher frequency can ablate dentin at a higher rate, they can cause a very high temperature rise. A modern laser unit (Biolase) used for cutting soft and hard oral tissues is shown in figure 4c.

A systematic review by Jacobsen et al. [46] evaluated randomized clinical trials that studied the efficacy of erbium lasers [47–53]. It was suggested that lasers are as effective as conventional rotatory instruments in removing dental caries. However, thermal injury to the dental pulp and the longevity of the restorations could not be assessed due to a lack of follow-up. Patients preferred laser ablation over conventional dental burs for being more comfortable. In most cases, local anesthetics were not required, which could hypothetically reduce treatment time by 5–10 min. Nevertheless, due to the lack of follow-up and further clinical trials, it was not possible to conclude the clinical feasibility of using lasers to ablate dental caries [46].

Cavity Preparation Using Ultra-Short Pulsed Lasers

Preliminary clinical trials suggest that erbium lasers are as efficient as conventional rotatory instruments in removing carious tooth structure. However, erbium lasers can cause pulpal necrosis due to thermal damage and require a copious amount of water spray during ablation. Ultra-short pulsed lasers (USPLs) have been shown to precisely cut hard materials including tooth enamel and dentin with less temperature rise than conventional lasers [54]. In a recent study [10], Nd:VO_4 USPLs were evaluated in terms of ablation rate and temperature changes for ablating dental hard tissues using radiation of variable wavelengths (355, 532, 1,045 and 1,064 nm). In general, USPLs demonstrated less temperature fluctuation and better ablation rate compared to erbium lasers. The rate of ablation was directly related to the wavelength and, hence, 1,045- and 1,064-nm lasers produced a higher rate of ablation than 355- and 532-nm lasers. It has been observed that femtosecond UPSLs provided dentin ablation with less collateral destruction of tooth structures compared to conventional lasers such as Er:YAG [55, 56]. More recently it was observed that lasers having a pulse rate as low as 66 fs can be used to ablate enamel and dentin [57]. Although temperature rise has been recorded with femtosecond UPS lasers, they are substantially controlled using air-coolant as evident by the low rise in temperature [58]. Additionally, femtosecond lasers have also been used to increase the adhesion of bonding agents with dentin by increasing the wettability [59]. Water-contact angle measurements have shown the contact-angle being as low as 0° when femtosecond UPSLs were used [59]. Another useful application of UPSL is the ablation of old restorations requiring removal or repair [60].

As mentioned earlier, one of the main advantages of using USPLs is the minimal temperature rise during cavity preparation [10], which may enable the operator to prepare the cavity without using a coolant. Hence, it improves the ability of the dentist to view the tooth and the surrounding tissues. The higher ablation rate of USPLs is also helpful in overcoming the problem of time-consuming laser cavity preparation. In spite of these promising results, more studies comparing the ablation rates of erbium lasers, USPLs and conventional rotatory instruments are required to confirm the superiority of USPLs in ablating tooth structure.

Etching prior to Bonding

Etching of enamel and dentin tissues produces characteristic surface features and is highly recommended for getting a strong bonding of resin restorations and tooth tissues. Conventionally, 37% phosphoric acid is used for acid-etching of tooth tissues [61]. Acid etching modifies the tooth surface at a microscopic level to facilitate the penetration of resin materials into the tooth surface for mechanical bonding [62]. Due to precise ablative properties, lasers are also used to etch tooth surfaces. For example, Nd:YAG lasers have produced comparable results to conventional acid etching [63, 64], whereas Er:YAG laser etching has produced a higher retention than phosphoric acid and a lower average shear bond strength [65]. Erbium-chromium lasers have also produced resin tags of similar size compared to acid-etched surfaces [66]. It has been observed that etching via Er:YAG laser followed by conventional acid etching improved the tooth-resin interface adhesion and higher bond strength compared to that produced by acid-etching alone [67].

Composite-Resin Curing

Etching of tooth tissue is followed by micromechanical bonding of the etched surface and the resin composite restorations [68]. Adhesive resin composites have gained popularity due to their white color and excellent aesthetic properties. Because the self-cured resin composites are nearly outdated due to shortcomings such as poor aesthetic and long working time, they have been replaced by modern light-cured composite materials. Laser-activated accelerator (camphorquinone) has been added to the resin-composite system [69]. Initial studies [70] suggested that there were no differences between conventional light-activated resins and argon laser-activated systems. However, the major advantage of laser-activated resins is the possibility to use a light source that has a significantly low power output [71] and improving the properties of the composite resins. There have been attempts to combine camphorquinone with other photoinitiators such as 1-phenyl-1,2-propanedione [72]. Spectrophotometric analysis suggested a synergistic effect of using these two initiators together. However, the cost of the laser itself has been a limiting factor in commercially available composite resins, as materials such as plasma arc-activated resins offer a similar rate and degree of polymerization as laser-activated systems at an affordable cost [72].

Removal of Restorative Materials

None of the available dental materials is ideal for dental restorations and no material is guaranteed to last indefinitely [73]. The excessive wear and tear in the harsh oral environment leads to damage of the restorations, which require removal and replacement from time by time. In other situations, extension of tooth decay or a new carious lesion may require the replacement of restorations. Conventionally, the removal of restorative materials is carried out using high- and/or slow-speed hand pieces and is accompanied by removal of healthy tooth structure, hence compromising the mechanical integrity of teeth and pulpal exposure [1].

In order to overcome the aforementioned risk factors of removing restorations using hand-held pieces, USPLs are being studied as an alternative method. In a recent in vitro study, the temperature rise was evaluated while using an USPL for the removal of different restorative materials [74]. The temperature rise recorded was theoretically sufficient to cause pulpal damages. However, in a recent study by Bello-Silva et al. [10] a much lower temperature rise was reported in dentin and enamel when an USPL was used to remove restorative materials. Dentin is considered a good thermal insulator; hence, if there is dentin remaining between the pulp and the restoration, it has the potential to protect the pulp from thermal damage. USPLs could be used an alternative conservative means to remove restorative materials so as to retain the protective dentin as much as possible. There is a need for more clinical studies to evaluate the consequences of lasers to the remaining tooth structure, including the pulp tissues, during the removal of restorative materials.

Management of Dentin Hypersensitivity

Dentin hypersensitivity is a condition where an individual has an exaggerated response to hot or cold stimuli. Dentin hypersensitivity is usually secondary to a number of conditions such as caries, gingival recession (exposed roots), tooth wear and microcracks. This is a very common clinical issue and lasers have been used to reduce dentin hypersensitivity by irradiation of dental hard tissues, for example CO_2, Er:YAG, GaAIAs, Nd:YAG and He-Ne [75]. A number of hypotheses have been proposed to explain their mode of action. It has been proposed that He-Ne lasers alter electrical activity in the pulpal nerve cells to make them less sensitive to pain [76]. Also, it has been speculated that GaAIAs lasers depress the C-fiber conductivity to reduce pain sensation [77]. The Nd:YAG and CO_2 lasers have been thought to occlude the dentinal tubules, thereby reduced dentin sensitivity [78, 79]. A clinical study suggested that a 660-nm GaAIAs laser is an effective dentin desensitizer for patients 25–35 years of age [80]. The Nd:YAG lasers can be combined with fluoride varnish to produce an effective protocol for treating dentin hypersensitivity [81]. More recently, an Er:YAG laser has been used in combination with a dentin-sensitizing agent to reduce discomfort [82]. In a systematic review [83], randomized controlled clinical trials using various lasers to reduce dentin hypersensitivity were analyzed. It was suggested that Er:YAG lasers had a higher efficacy in reducing dentin sensitivity compared to Er,Cr:YSSG and GaAIAs [83]. Although more clinical trials are required to assess the long-term efficiency of using these lasers to reduce dentin hypersensitivity, research to date suggests that lasers offer a promising alternative to conventional methods of reducing hypersensitivity

Pain Control Using Low-Level Light/Laser Therapy

It has been understood that exposure to low-level light/lasers (GaAIAs) reduces pain and induces tissue repair [84]. A clinical study conducted on 26 patients undergoing fixed orthodontic treatment suggested that low-level light/laser therapy (LLLT) was beneficial in alleviating pain and inflammation [85]. However, a clinical trial investigating the validity of using LLLT on postsurgery patients did not find any significant effects on postoperative pain [86]. Nevertheless, more studies are needed to ascertain whether LLLT could be beneficial in reducing the discomfort of patients who have undergone restorative dental procedures such as fillings and crown preparations.

Photobiomodulation

A number of studies [87, 88] have used the term ‘photobiomodulation’, or PBM, to replace LLLT. It was observed in animal studies that using lasers such as GaAlAs (wavelength ~780–830 nm) to irradiate implant placement sites promoted faster healing compared to sites not receiving any laser therapy [88, 89]. This faster healing of tissues was thought to be linked to the increased adenosine triphosphate activity that in turn accelerated the proliferation and differentiation of osteoblasts, enhanced bone turnover and angiogenesis. In addition, Raman spectroscopic studies revealed higher levels of calcium hydroxyapatite in irradiated animal tissues compared to control groups [88]. In addition, PBM-treated implant sites exhibited higher mean removal torque levels, suggesting a higher primary stability and an enhanced long-term mechanical permanence [90].

Removal of Extrinsic Stains and Dental Bleaching

Public awareness and recent advancements have increased the demand for cosmetic dental procedures in clinics. Many substances such as coffee, tea, wine, mouth washes, nicotine and metallic salts cause external staining of dental enamel [91]. Conventionally, there are many methods to remove external stains, including micro- or macroabrasion and hydrogen peroxide bleaching [92]. In certain cases, prolonged accumulation of these substances causes the extrinsic stains to be ‘internalized’ into the outer layer of the dental enamel, which could cause difficulties in bleaching treatment [91, 93].

The heat energy produced from laser application is utilized to remove stains with ease. A recent study by Schoenly et al. [94] tested the feasibility of using a near-UV laser (60-ns pulse rate) to remove internalized extrinsic stains on enamel. The laser was able to remove the stains, leaving a smooth enamel surface. In addition, any affected underlying enamel is ablated using this technique. Photochemical and photothermal bleaching are used for the removal of intrinsic stains. Argon KTP diode CO_2 lasers (515, 532, 810–980 and 10,600 nm) are used for tooth bleaching applications [25].

Pulpotomy

Pulpotomy is a procedure of devitalizing the pathological coronal dental pulp using medicaments such as formocresol to restore the tooth by means of a suitable restorative material such as glass ionomer-based cements. However, formocresol (the most commonly used pulp devitalizing agent) has the potential to cause toxic and carcinogenic adverse effects [95, 96]. Although materials such as calcium hydroxide and ferric sulfate exhibit less adverse effects than formocresol, conventional caries removal is still essential before their application.

Laser treatments using Er,Cr:YSGG have been compared to formocresol pulpotomy procedures on primary teeth of dogs [91]. Histological examination has revealed that a laser has a more favorable response compared to formocresol. The stress of conventional dental treatment is another issue and may require pain and anxiety control using sedative agents [97]. Ablating teeth with lasers does not require the administration of local anesthesia; therefore, they are more effective for cavity preparation than conventional means in patients with dental anxiety.

Indirect Restorations Using CAD/CAM Lasers

In order to replace lost teeth or dental tissue, an accurate impression (negative replica of oral tissues) is required. Conventionally, it is achieved using hydrocolloid or rubber base impression materials and casting model/die. However, these materials are linked to a number of adverse effects such as dimensional changes, infection, and intolerance or gagging in certain patients [28, 29]. Alternatively, lasers are used to scan intraoral tissues to create 3D digital impressions [98] and fabricating indirect restorations using the CAD/CAM technology. Occlusal contacts can be scanned 3-dimensionally using lasers [99].

In addition to CAD/CAM, the stereolithography technique is used for laser-activated polymerization of resins in incremental layers and for constructing the dental prostheses such as temporary resin restorations. Lasers are also being used to create restorations by melting fine layers of powder [17]. Molten powder granules present in each layer fuse together to form a layer of a solid. New layers are added on top of each other to create different prostheses. This process is known as selective laser melting or laser sintering [17]. Another useful application of 3D laser scanning is the measurement of occlusal wear of different restorations; it was reported to be more accurate, faster and simpler than other methods [100, 101].

Contouring Gingival Margins

Lasers are used for contouring gingival margins, crown lengthening, correct crown asymmetries and optimizing crown proportions [102]. Normally a pulsed diode laser at a wavelength of 812–980 nm is preferred for cosmetic gingival surgery. These laser procedures are not time consuming and cause considerably less discomfort and bleeding than other types of lasers [103]. Similarly, pulsed Nd:YAG lasers have also been reported to induce less peri- and postoperative bleeding compared to gingival contouring carried out using surgical scalpels [104].

Periodontal Healing

In addition to conventional and contemporary guided tissue regeneration, lasers have also been used to induce regeneration and healing of periodontal tissues. A histological in vitro study by Belal et al. [105] suggests that CO_2 and Er:YAG lasers promote periodontal ligament attachment when used to irradiate periodontal tissues. Similar findings were reported by Kreisler et al. [106] while using low-level lasers to promote proliferation of human PDL cells. Furthermore, low-level Er:YAG lasers have been shown to simulate the proliferation of gingival fibroblasts [107]. Considering these facts, it can be assumed that these lasers can be used for postrestorative procedures involving gingiva and periodontium.

Decontamination of Dental Devices

Lasers have also been used to decontaminate dental devices such as oral implants [7]. Although Nd:YAG lasers have not able to produce any significant antibacterial effects when used to irradiate dental implants [84], low-energy Er:YAG lasers have demonstrated effective sterilization of dental implants [108] without damaging the surface topography. In a more recent study, 100% elimination of bacteria was achieved with Er:YAG and CO_2 lasers [109]. Therefore, lasers have the ability to sterilize metal and alloy instruments including hand pieces and endodontic files without any adverse effects.

Conclusions

Lasers represent cutting edge technology for a wide range of restorative dental applications with promising outcomes. Despite the remarkable benefits, lasers are not commonly used for many procedures, particularly in developing countries. Many factors contribute to this, such as high cost, technique sensitivity, and lack of training and updates among dental professionals. Considering recent developments as a result of continuous research and technology advancement, a remarkable increase in the applications of lasers for dental application is expected in the near future. In order to cope with the rapidly growing laser technology, it is highly recommended that dental professionals consider updating their knowledge and skills by means of continuous professional development, training courses and literature updates.

Disclosure Statement

The authors report no conflicts of interest.

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