Digitization and Dental Lasers

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5.1 Introduction

Lasers have gained immense use due to the optimization of the wavelength for human tissue interactions. Initially, dental lasers were primarily used for soft tissue surgical procedures, such as excisions and incisions. Instruments then evolved for use on both hard and soft oral structures [1, 2]. Photobiomodulation (PBM) is now universally used as a substitute for low-level laser therapy, has been shown to have a positive effect on living tissues, and as such have been used as a noninvasive alternative in the treatment of various pathological conditions [3, 4].

The biomedical and therapeutic application of the photonic energy is based on the light-tissue interactions leading to laser absorption by cellular components such as mitochondria cytochromes and endogenous chromospheres, which give rise to phenomena such as fluorescence, chemical reactions, and thermal effects [5].

PBM is NOT a thermal interaction in the sense of significantly raising the tissue temperature. These laser therapies often involve red blood cells due to the high optical absorbance of hemoglobin; thus, have proved to be the "most versatile" [6, 7]. The red blood cells are also found in many organs in high concentration. Therefore, the damaging effect of these irradiations occurs at the cell level since hemoglobin is located in red blood cells [8]. The damage is thermal and is related to mechanical stress, vapor bubbles, and overheating because of irradiation [9]. These

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physiological phenomena stimulate other processes in the cell such as enzyme inactivation, alteration of metabolic rate, and coagulation among other structural changes in the cell [10].

Important effects of low-energy laser light have been highlighted in the scientific works of literature, which are tissue regeneration, reduction of inflammation, pain relief, and immune system enhancement [11]. The low-energy intensity lasers have in recent years being used in the noninvasive treatment of musculoskeletal and cutaneous complications and have also gained increased use in wound healing, nerve repair, and pain management, among other clinical applications. In diabetic conditions where wound healing is compromised, low-energy intensity lasers have shown beneficial effects of healing impaired wounds [12, 13].

Laser used in clinical dentistry has spanned over 30 years. Prior to that, carbon dioxide lasers (CO_2, wavelength 10.6 μm) were used in general medical surgeries and subsequently were applied to the soft tissue surgical procedures within the mouth [14]. Neodymium YAG (1.064 μm) was the first dental laser which was launched in 1989, and from there the next 10 years witnessed the emergence of different major wavelengths Er:YAG and Er,Cr:YSGG and diode semiconductor-based technology [15, 16].

5.2 Laser and its Components

LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation, which is based on theories and principles first put forth by Einstein in the early 1900s.The first actual laser system was introduced by Maiman in 1960 [17].

Laser energy is a man-made product and consists of photons of a single wavelength. The process of lasing occurs when an excited atom is stimulated to remit a photon before it occurs spontaneously; spontaneous emission of light results in unorganized light waves similar to light emitted by a light bulb [18]. **Stimulated emission** of photons generates a very coherent, collimated, monochromatic ray of light that is found nowhere else in nature. As that light is so concentrated and focused, it can have a decided effect on target tissue at a much lower energy level than natural light. The effect of laser energy on target tissue is dependent on its wavelength, which is determined by the lasing medium inside the laser device [19].

Laser irradiation is a type of electromagnetic radiation which exhibits the properties of a wave, and discrete energy packages referred to as photons. The short wavelengths such as high-energy ionizing irradiation cause the ionization of molecules in an indiscriminate manner with the far-infrared heating biological tissues [20, 21].

Materials, which can be used for stimulation to produce lasers, include ruby, dyes, crystals of common and rare earth minerals, semiconductors, and mixtures of gases [20]. Each will produce a laser of different wavelength. Lasers can be further categorized into four groups:

- Gas discharge lasers.
- Semiconductor diode lasers.

- Optically pumped laser.
- The final group that consists of X-ray lasers, combustion lasers, chemical lasers, and gas dynamic lasers.

Gas discharge lasers include the common type: helium neon lasers, carbon dioxide lasers, noble gas lasers. Semiconductor lasers include the high-power diode laser. The optically pumped laser uses photons of light to pump directly the lasing medium to higher energy levels [22, 23]. Lasers have their basic components, which are the power source, which provide energy, lasing medium (which is the active medium and can be solid or gas), and reflecting mirrors (two or more in number that forms an optical cavity or a resonator) with production of light of particular wavelength, which defines the type of laser as shown in Fig. 5.1.

The optical cavity contains the active medium and reflective surfaces. Initial energy is provided by an excitation source. Photons within the active medium are reflected, amplified, and then collimated. Those are emitted into a lens assembly, which then produces the useful laser beam [24].

In a diode laser, the semiconductor medium is a wafer that contains layers of positively and negatively charged compounds, bounded by reflective coating. Several of these wafers are grouped together to produce a useful laser beam [25, 26].

Laser radiation is specific wave generated and is a highly focused directional beam as opposed to the visible light which is mainly white light and nondirectional and nonfocused. Commercially available dental laser instruments all have emission

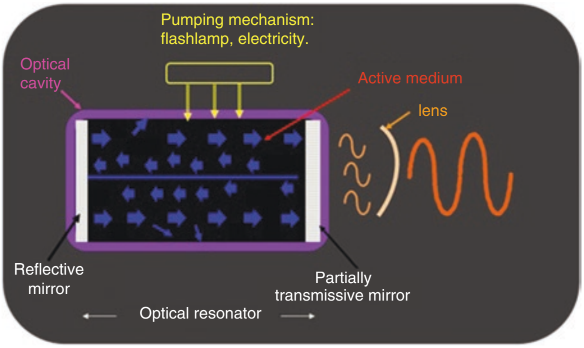

Fig. 5.1 A representational graphic of the basic components of a dental laser. The optical cavity contains the active medium and reflective surfaces. Initial energy is provided by an excitation source. Photons within the active medium are reflected, amplified, and then collimated. Those are emitted into a lens assembly, which then produces the useful laser beam. In a diode laser, the semiconductor medium is a wafer that contains layers of positively and negatively charged compounds, bounded by reflective coating. Several of these wafers are ganged together to produce a useful laser beam

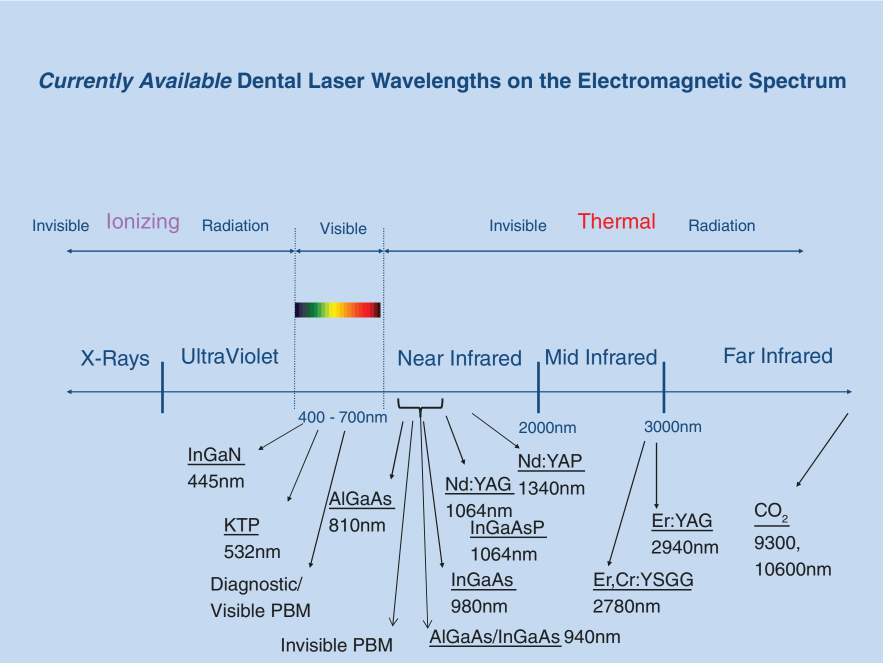

Fig. 5.2 Approximate absorption curves of the currently available dental laser wavelengths. The curves represent hemoglobin, melanin, water, and tooth enamel (carbonated hydroxyapatite.) Above the light green line, there is absorption, and below it is transmission of the photonic energy

wavelengths in the range of 488 nm to 10,600 nm [27, 28]. All are of nonionizing radiation and span the visible, near, mid, and far-infrared portions of the electromagnetic spectrum as shown in Fig. 5.2.

5.3 Laser Delivery Systems and Laser Emission Modes

Laser energy can be delivered to the surgical site by various means that are accurate and precise. These include the fiber-optic system, hollow fiber, articulated arm delivery system, and handpieces [29, 30]. See Figs. 5.3 and 5.4 below.

Lasers in the visible (445 and 532 nm) and near-infrared (from 810 nm to 1064 nm) range use fiber-optic strands by means of a handpiece with straight and precise tips that deliver the laser energy to the target tissue. This type of delivery system can degrade with time but is lightweight with a good tactile sensation and is easy to use and sterilize. Some newer models have more rugged fibers [31].

Erbium and CO_2 devices are lasers with more rigid glass fibers, semiflexible hollow waveguides, or articulated arms. However, there is a loss of energy over time with lack of control due to internal reflection, with these systems [5]. For

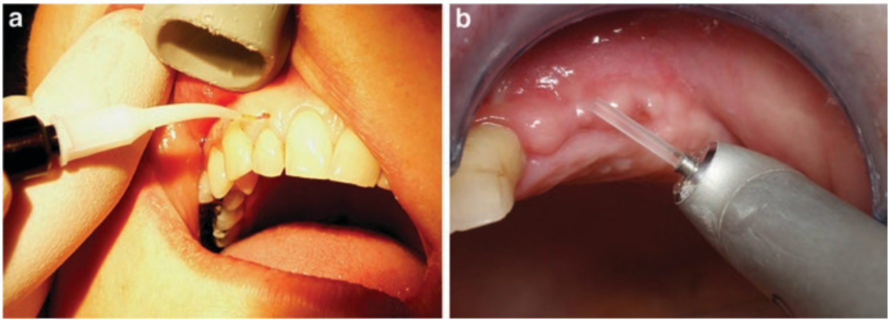

Fig. 5.3 (**a**) A small diameter glass fiber is paired with a disposable tip, used in contact with the target tissue. (**b**) A fiber optically delivered laser with a handpiece and a reusable tip, employed slightly of contact with the target tissue

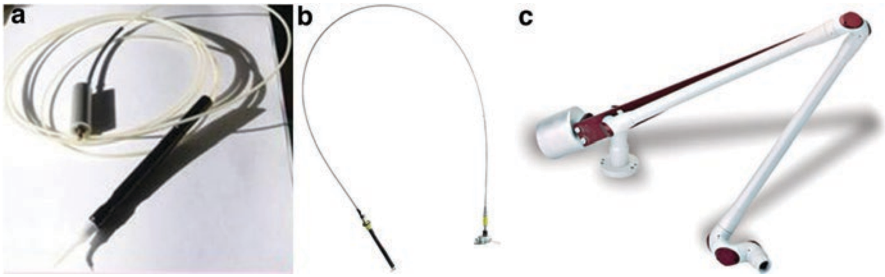

Fig. 5.4 (**a**) An optic fiber. (**b**) A hollow waveguide. (**c**) An articulated arm assembly. Usually, with an optic fiber, the laser beam is emitted with a contact tip; conversely with a hollow waveguide or an articulated arm, the beam is delivered without a tip in a non-contact mode

hard tissue procedures, a water spray is used for cooling, and that can be switched off for soft tissue surgery. In addition, lasers with articulated arm delivery systems utilize a progression of verbalized mirrors (generally 7) associated one to each other, prompting transmission of vitality [32, 33].

Two basic emission modes are used for dental lasers, based on their excitation source:

1. Continuous wave mode where the laser energy/beam is transmitted continuously as long as the laser is activated. Carbon dioxide, argon, and diode lasers operate in this manner. Variations in this mode include the "gated emissions" where there is a periodic alteration of the laser energy being on or off (similar to blinking), thereby preventing laser light transmission. This design helps minimize some of the undesirable residual thermal damage associated with continuous wave devices. It is very important to pay attention to this effect during laser use in order to protect damage to the surrounding tissues. Some of the recent models of "gated" lasers feature pulse durations in the microsecond range.

2. Free-running pulse lasers only operate in a unique pulsed mode, never continuously, where emission is in very short pulses in the microsecond range followed by a long time when the laser is off. Nd:YAG and Er:YAG as well as Er,Cr:YSGG devices operate as free-running pulsed lasers.

5.4 Types of Tissue Interactions

When laser light is exposed to the tissue, it can reflect, scatter, be absorbed, or be transmitted to the surrounding tissues. Different wavelengths have different absorption coefficients, and this property accounts for their variable effect on human tissue as shown in Fig. 5.5. The curves represent hemoglobin, melanin, water, and tooth enamel (carbonated hydroxyapatite.) Above the light green line, there is absorption, and below it is transmission of the photonic energy [34, 35].

The hydroxyapatite crystals of teeth and bone absorb carbon dioxide, and the erbium family's photons. The visible and near-infrared wavelengths have virtually no interaction with either enamel or water. The erbium family is very highly absorbed in water, while carbon dioxide is about 10 times less absorbed [21]. All wavelengths have different depths of penetration through soft tissue because of the different water

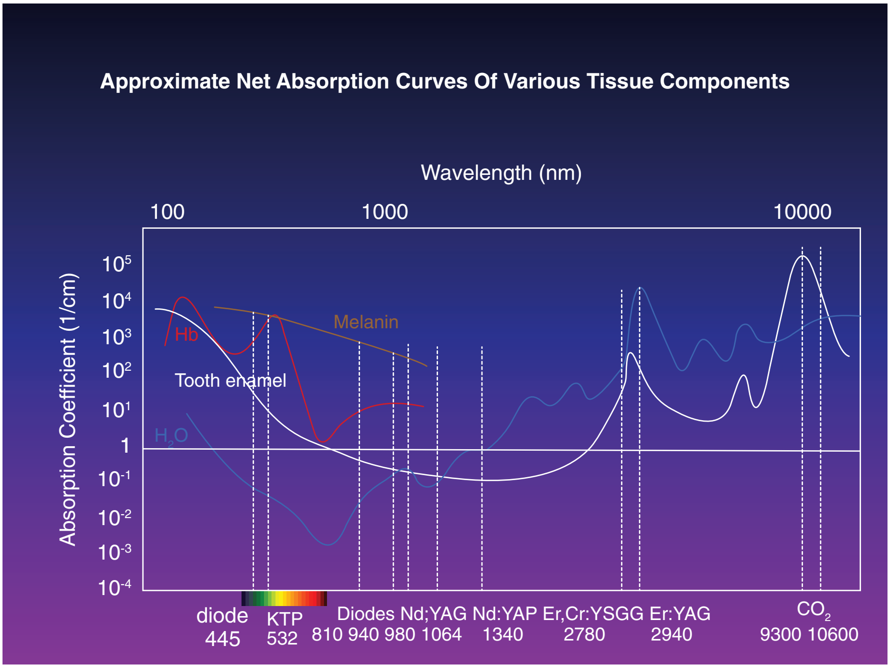

Fig. 5.5 Approximate absorption curves of the currently available dental laser wavelengths

absorption characteristics. Diode lasers can reach deeper into the tissue approximately several thousand layers, whereas the erbium lasers are absorbed on the surface [33, 36].

Lasers can have various effects on the target tissue. One effect is photothermal: simply stated, light is converted to heat. When the tissue absorbs the photonic energy used during surgical procedure, it elevates the temperature. When a temperature of 100 °C is reached, vaporization of the water within the tissue occurs. This process is called ablation. At temperatures between 60 and 100 °C, denaturization of the proteins starts occurring, without dehydrated and then burned, resulting in an undesirable effect called carbonization or vaporization [37, 38].

Nonsurgical, low-level power laser applications include photo-bio modulation (PBM), diagnostics, photo-activated antibacterial processes, laser tooth whitening, and laser scanning of tooth cavity preparations [39]. Another effect is photochemical effects such as curing of the composite resin [40]. Lastly, some lasers can also produce tissue fluorescence, which is used as a diagnostic method for caries detection [41, 42].

5.5 Lasers in Dentistry

The use of LASER technology in the dental industry is a subject of continuous researches and advancements. In Fig. 5.6**,** a systematic review on how the laser interacts with the dental tissue is shown.

Table 5.1 lists the currently available dental lasers whose emission is on the *visible spectrum.*

The currently available dental lasers whose emission is in the *invisible spectrum* is listed in Table 5.2**.**

5.6 Lasers Generally Practiced in Dentistry

5.6.1 Carbon Dioxide Laser

CO_2 laser's photonic energy has a very high affinity for water; it causes rapid soft tissue removal and hemostasis. The penetration of depth is relatively shallow. A newly available model of CO_2 with ultrashort pulse duration can be used for hard and soft dental tissue.

5.6.2 Neodymium Yttrium Aluminum Garnet Lasers

Absorption of this wavelength is high in pigmented tissue; therefore, it is sufficient for cutting and coagulating dental soft tissues, with high-grade hemostasis. Other uses include nonsurgical periodontal therapy.

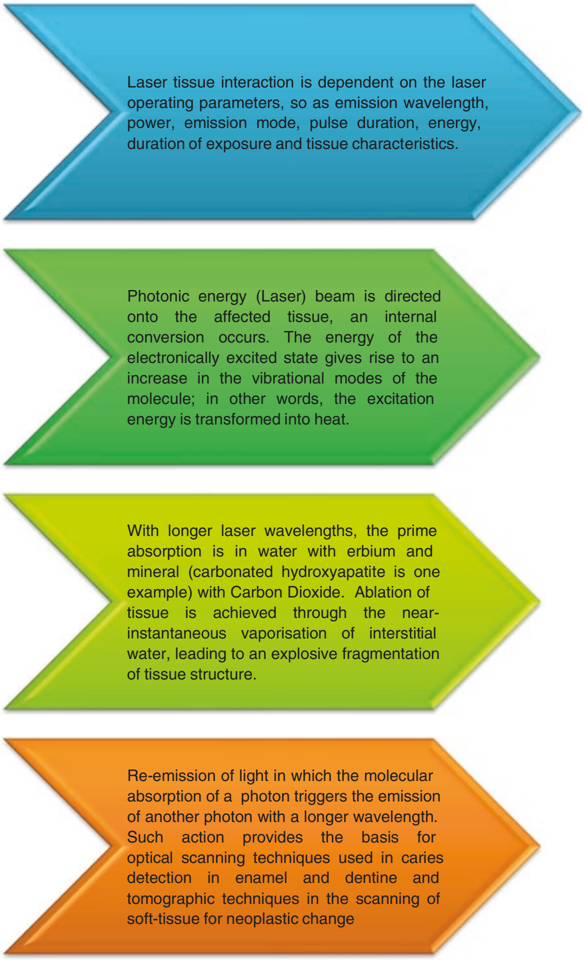

Fig. 5.6 How the laser works on the tooth

Table 5.1 lists the currently available dental lasers whose emission is on the **visible spectrum.** Column 1 lists the generic name of the laser and the color of light emitted; column 2 describes the typical uses of that laser; column 3 lists the elements of the active medium; column 5 lists the emission wavelength; and column 5 shows abbreviations for the emission modes

Generic name of laser	Typical uses	Active medium	Emission wavelength	Emission mode
Semiconductor diode, visible blue	Soft tissue procedures, tooth whitening	Indium gallium nitride	445 nm	CW, GP
KTP solid state visible green	Soft tissue procedures, tooth whitening	Neodymium-doped yttrium aluminum garnet (**Nd:YAG**) and potassium titanyl phosphate (**KTP**)	532 nm	CW, GP
Low-level lasers, visible red semiconductor, or gas lasers	Photobiomodulation therapy (PBM), photodynamic therapy (PDT), or carious lesion detection.	Variations of gallium arsenide or indium gallium arsenide phosphorus diodes Helium neon gas	600–670 nm 632 nm	CW, GP

CW continuous wave, *GP* acquired or gated pulse

Table 5.2 This table lists the currently available dental lasers whose emission is on the **invisible spectrum**. Column 1 lists the generic name of the laser; Column 2 describes the typical uses of that laser; Column 3 lists the elements of the active medium; Column 4 lists the emission wavelength or range of wavelengths; and Column 5 shows abbreviations for the emission modes

Generic name of laser	Typical uses	Active medium	Emission wavelength (nm)	Emission mode
Low-level diode lasers, near infrared	Photobiomodulation therapy (PBM), photodynamic therapy (PDT)	Variations of aluminum gallium arsenide diodes	800–900	CW, GP
Semiconductor diode, near-infrared	Soft tissue procedures	Aluminum gallium arsenide	800–830	CW, GP
Semiconductor diode, near-infrared	Soft tissue procedures	Aluminum/indium gallium arsenide	940	CW, GP
Semiconductor diode, near-infrared	Soft tissue procedures	Indium gallium arsenide	980	CW, GP
Semiconductor diode, near-infrared	Soft tissue procedures	Indium gallium arsenide, phosphorus	1064	CW, GP
Solid state, near-infrared	Soft tissue procedures	Neodymium-doped yttrium aluminum garnet (**Nd:YAG**)	1064	FRP
Solid state, near-infrared	Soft tissue procedures, endoscopic procedures	Neodymium-doped yttrium aluminum perovskite (**Nd:YAP**)	1340	FRP
Solid state, mid-infrared	Soft tissue procedures, hard tissue procedures	Erbium, chromium-doped yttrium scandium gallium garnet (**Er,Cr:YSGG**)	2780	FRP
Solid state, mid-infrared	Soft tissue procedures, hard tissue procedures	Erbium-doped yttrium aluminum garnet (**Er:YAG**)	2940	FRP
Gas, far infrared	Soft tissue procedures, hard tissue procedures	Carbon dioxide (**CO_2**) laser, with an active medium isotopic gas	9300	FRP
Gas, far-infrared	Soft tissue procedures	Carbon dioxide (CO_2) laser with an active medium of a mixture of gases	10,600	CW, GP, FRP

CW continuous wave, *GP* acquired or gated pulse, *FRP* free running pulse

5.6.3 Erbium Laser

The family of erbium lasers has two distinct wavelengths, Er, Cr: YSGG lasers and Er: YAG lasers. Erbium wavelengths have a secondary affinity for hydroxyapatite crystals and the most powerful absorption of water in any dental laser wavelength. It is the laser of selection for treatment of dental hard tissues, and can be used for soft tissue ablation because the dental soft tissue comprises a large percentage of water.

5.6.4 Diode Laser

The diode laser is a solid-state semiconductor containing various combinations of aluminum, gallium, arsenide, and occasionally indium producing different laser wavelengths, varying from approximately 445 to 1064 nm. These wavelengths are absorbed principally by tissue pigment melanin and hemoglobin, and inadequately absorbed by hydroxyapatite and water.

Dental lasers have a number of its applications in dentistry as given in Table 5.3**.** Considering that the light emitted serves both the goals of removing or shaping tissue, a number of functions can be performed.

5.7 Soft Tissue Application

5.7.1 Photobiomodulation

It is also known as "soft laser therapy" and is based on the concept that low level of doses of specific coherent wavelengths can turn on or turn off certain cellular components or functions. At low laser doses (2 J/cm^2), laser utilization stimulates proliferation, while at large doses (16 J/cm^2) it is suppressive [43, 44]. This technique induces analgesic, anti-inflammatory, and biomodulation effects at molecular level

Table 5.3 Uses of lasers in dentistry

Specialty	Uses
Oral surgery	Major or minor surgical procedures such as flap surgeries, frenectomies, removal of hyperplastic tissues, operculectomy, excisional biopsy, root end resection, gingivectomy procedures, exposure of impacted teeth, and vestibuloplasty Treatment of abscess, aphthous ulcer, granuloma, epulis, irritation fibroma Hemangioma and curettage
Periodontics	Flap surgery, frenectomy, gingival contouring/gingivectomy, pocket treatment
Orthodontics	Post orthodontic removal of residual cement Exposure of impacted teeth
Endodontics	Bleaching Canal irrigation Root resection in endodontic surgeries
Prosthetic and restorative dentistry	Caries removal Curing of material Removal of fractured restorations Etching of the tooth Sulcus deepening Crown contouring and lengthening Smile design
Pediatric dentistry	Removal of caries in deciduous teeth Pulpotomy and pulpectomy procedures

improving tissue healing processes and less postoperative discomfort for patients, without any negative effects [10, 45]. This technique is most useful in medically compromised patients where wound closure and tissue healing is of prime importance.

LLLT (low level laser) results in vasodilation of the cells, which causes increase in local blood flow, relaxation of smooth muscles, thus bringing in oxygen and further migration of immune cells to the targeted tissue. This in turn results in rapid maturation and regeneration [9, 46]. Accurate effects of PBM on the healing of lesions of recurrent aphthous stomatitis in humans have been recorded. Research has shown that LPL encourages healing and dentinogenesis following pulpotomy. This makes it useful in the healing of mucositis and oropharyngeal ulceration in patients enduring radiotherapy for head or neck cancer [47, 48].

Photostimulation of aphthous ulcers and recurrent herpetic lesions, with low power laser energy (He-Ne), can provide pain relief and accelerate the healing process. In recurrent herpes simplex labialis lesions, lesions get arrested before painful vesicles form, thus expediting the overall healing time, and minimizing the frequency of recurrence (Figs. 5.7 and 5.8) [49–51].

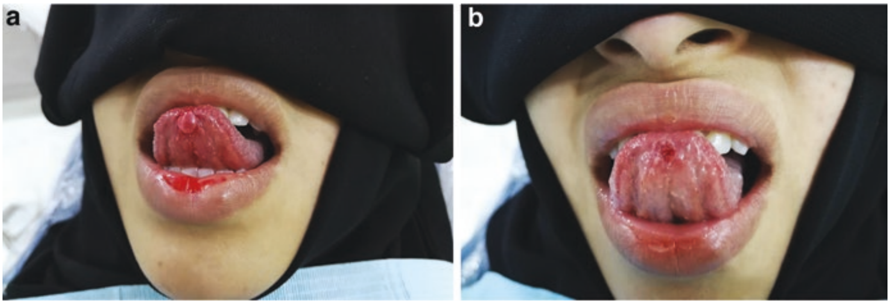

Fig. 5.7 Tongue mucosal using diode laser (980 nm). (**a**) Before laser treatment. (**b**) After laser treatment

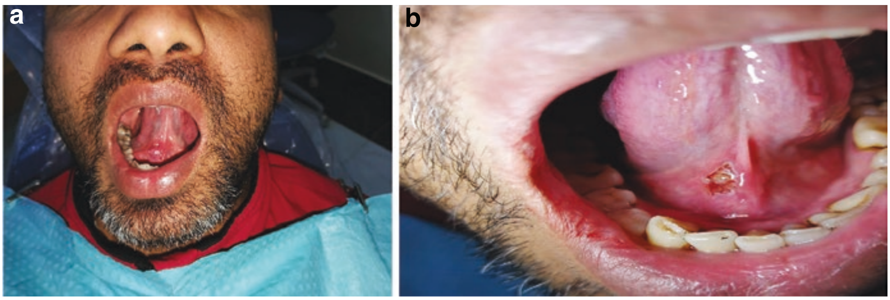

Fig. 5.8 Lingual papilloma using diode laser (980 nm). (**a**) Before laser treatment. (**b**) After laser treatment

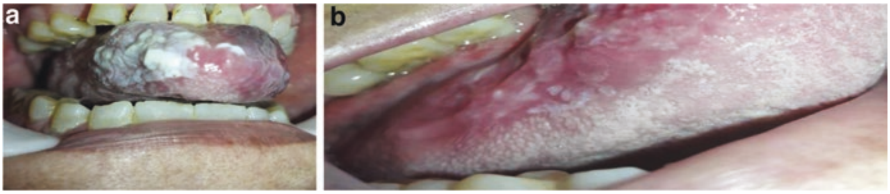

Fig. 5.9 Laser-assisted surgery for removing tongue leukoplakia using diode laser (980 nm). (**a**) Before laser treatment. (**b**) After laser treatment

Low-level laser energy is beneficial for photochemical activation of oxygen, releasing dyes, creating membrane and DNA damage to the microorganisms [52]. Photoactivated dye technique can be engaged with a system utilizing low power laser (100 mill watts) in visible red (semiconductor diode lasers) and toluidine blue dye. Studies have shown photoactivated disinfection (PAD) to be effective in killing bacteria: gram-positive bacteria including methicillin-resistant *Staphylococcus aureus*, gram-negative bacteria, fungi, viruses in complicated biofilms like subgingival plaque (Fig. 5.9) [53, 54].

The clinical applications of PAD involve disinfection of root canals, periodontal pockets, deep carious lesions, and sites of peri-implantitis. Tolonium chloride is practiced in high concentrations for screening patients, for malignancies of the oral mucosa and oropharynx [55, 56].

5.7.2 Photodynamic Therapy for Malignancies

Clinical investigations have published positive effects for the photodynamic therapy (PDT) of carcinoma in situ and squamous cell carcinoma, with the oral cavity, with acknowledgement rates approximating up to 90% [8, 57].

5.7.3 Soft Tissue Surgery

Soft tissue excisions can easily be performed using lasers. The targeted lesion is grasped with forceps or a similar instrument, with the laser beam directed towards the healthy tissue peripheral to the lesion. Care is needed not to tear any structures but rather allow the laser energy to do the work [58, 59]. Fig. 5.10 depicts an erbium laser removal of an irritation fibroma.

Low average power laser is used in *endodontic therapy procedures* such as post pulpotomy (with the laser beam applied directly to the remaining pulp and on the mucosa toward the root canal pulp); post pulpectomy (with the irradiation of the apical region); and periapical surgery (irradiating the mucosa of the area corresponding to the apical lesion and the sutures) [60, 61].

A fiber-supported laser delivery system with appropriate diameter tips (such as erbium lasers) and capable of delivering laser energy laterally is used for intracanal

Fig. 5.10 (**a**) An irritation fibroma on the left mucosa, preoperative view. (**b**) An erbium laser was used to remove the fibroma, immediate postoperative view. There is minimal thermal tissue damage and good hemostasis. (**c**) One week postoperative view of surgical site with good healing

Fig. 5.11 (**a**) A single periodontal pocket with inflammatory tissue. (**b**) After the removal of biofilm, the diode laser is used to remove the diseased epithelial lining, reduce the bacterial population, and provide hemostasis. (**c**) Six month postoperative view shows periodontal health with no tissue recession

application [62]. However, the currently available laser energy output cannot shape the sides of canals. The ability to significantly reduce the bacterial contamination of the root canal system by disinfection, via the bactericidal effect of thermal interaction, is an advantage of the laser, and further development will enhance the use of lasers in endodontic therapy [63].

In *Periodontics,* depending on absorption characteristics, different lasers can be used in procedures such as gingivectomy, gingivoplasty, scaling and root planning, and removal of sulcular epithelium. While comparing lasers with conventional periodontal surgical procedures, reduction in plaque index, bleeding index, pocket depth, and better reattachment was observed [64, 65]. The devices used should be of thin fiber so that it can be easy on the soft tissue lining of the pocket. The energy used would be less than one-half that employed for surgical excision.

Figure 5.11 demonstrates a diode laser used adjunctively for treatment of gingivitis. Figure 5.12 shows a diode laser adjunctively treating peri-implant mucositis.

Another use of the laser in periodontics is for soft tissue management for impressions of indirect restorations. Fig. 5.13 depicts the use of a diode laser for tissue retraction and hemostasis prior to impression taking for two ceramic anterior crowns.

All dental wavelengths, including diode and Er,Cr:YSGG, can be used in removal of hyperplastic gingival tissues, due to its characteristic of less postoperative pain and absence of scarring etc., as opposed to conventional methods [66, 67].

Fig. 5.12 (**a**) View of peri-implant mucositis on the lower right second molar implant fixture. (**b**) Prior to diode laser use, biofilm and other accretions removed from the implant with hand instruments. View shows diode laser is use to remove the diseased soft tissue, offer bacterial reduction, and provide hemostasis. (**c**) Four month postoperative probing demonstrates healthy tissue and implant stability

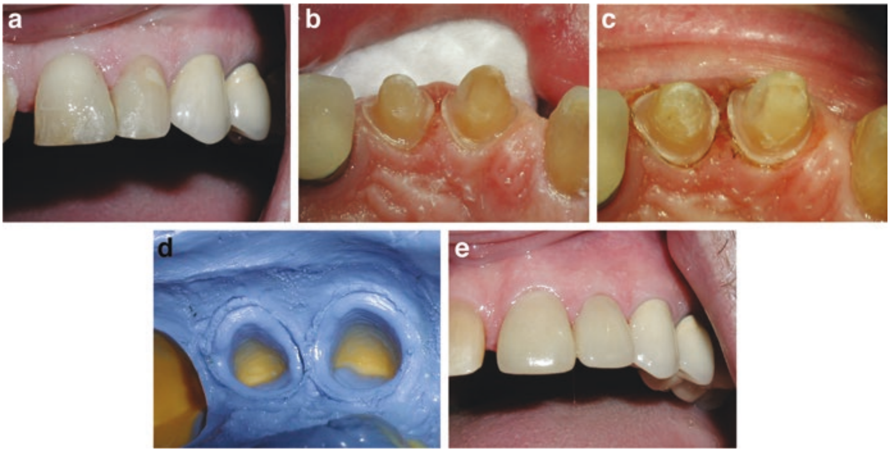

Fig. 5.13 (**a**) Maxillary left central and lateral incisors that will receive full porcelain crown restorations. (**b**) Completed preparations before any gingival tissue manipulation. (**c**) Diode laser used for tissue retraction and hemostasis, immediate postoperative view. Note completely dry field. No conventional retraction cord was used. (**d**) Immediately after laser use, an impression was taken. There is no debris and excellent detail. (**e**) Restorations placed 2 weeks later. The tissue height and tone responded well to the laser tissue retraction

Figure 5.14 shows preoperative gingival enlargement and immediate postoperative tissue removal using diode laser.

Gingivectomy with Er:YAG, Er,Cr:YSGG laser is advised for immunocompromised patients and in the removal of plaque/calculus from root surface with sufficient water cooling [68, 69]. A diode laser can also be used, although hyperplastic tissue can be very challenging to remove with the diode. However, normal tissue can be excised with good results. Fig. 5.15 shows the uncovering of a fully integrated implant fixture, and Fig. 5.16 shows soft tissue gingivectomy for an aesthetic procedure.

Crown lengthening procedures can also be done using a laser. Diode lasers and Nd:YAG have proven useful in removing soft tissue effectively without damage to

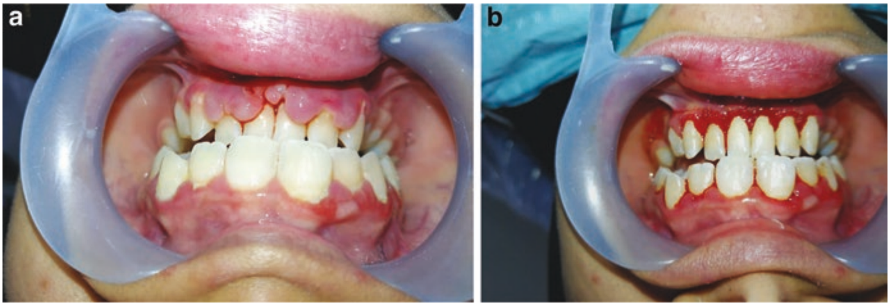

Fig. 5.14 Gingival enlargement using diode laser (980 nm). (**a**) Before laser treatment. (**b**) After laser treatment

Fig. 5.15 (**a**) Uncovering of implant fixture using a diode laser. (**b**) Two week postoperative view of the tissue around the implant fixtures. The healing cap from the most distal fixture has been removed, showing the excellent tissue tone. (**c**) One week later, the final abutment copings are placed. Note the excellent soft tissue tone and contour

Fig. 5.16 (**a**) Preoperative view of excessive gingival tissue with shortened clinical crown display. (**b**) Biologic width was measured to ensure that adequate tissue was available for excision. A diode laser performed gingivectomy and gingivoplasty. The desired contours are easily placed with the laser and hemostasis is excellent. Immediate postoperative view. (**c**) Good tissue tone and contour are shown with an acceptable aesthetic result. Six month postoperative view

the surrounding tissues, while erbium lasers can be used to expose root structure [70]. The tissue removal should be done in such a way that biological width is always maintained. Water cooling should be used when working with erbium lasers on hard tissues [71]. Figure 5.17 shows osseous crown lengthening performed with an erbium laser.

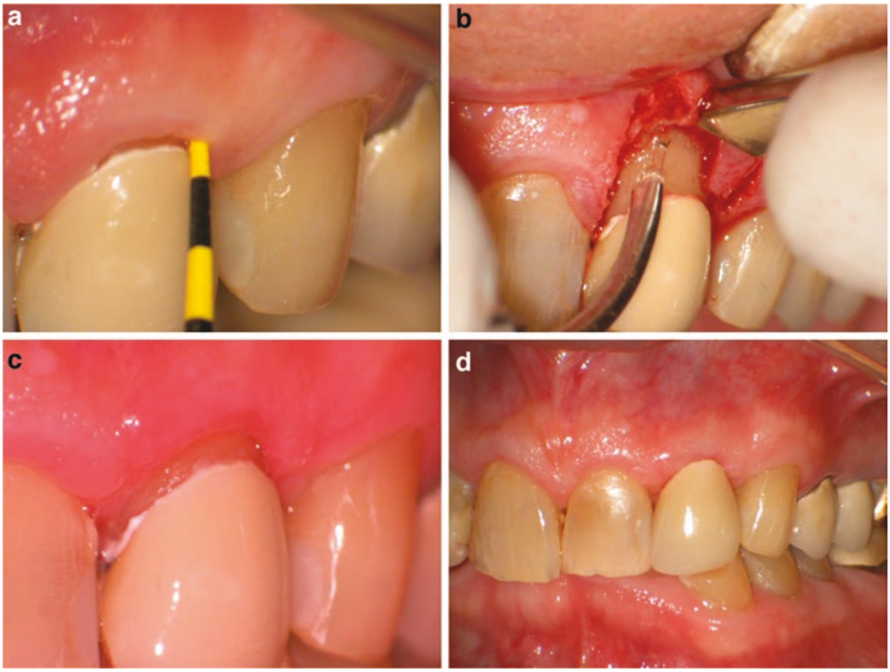

Fig. 5.17 (**a**) A new crown is necessary on an endodontically treated maxillary left central incisor because of a fracture of half of the remaining tooth structure. Periodontal probing shows inadequate biologic width for the proposed new subgingival margin placement. (**b**) After the tooth structure was built up, an open flap procedure and an erbium laser was used to remove labial bone and establish a new osseous contour. (**c**) The periodontal tissue has healed and adequate tooth structure is now available for a restoration. Six weeks postoperative. Note good soft tissue tone and contour. (**d**) Eight weeks postoperatively, the new crown has just been cemented

In *orthodontics*, an unerupted or partly erupted tooth can be revealed for bonding via conservative tissue removal, for reasonable positioning of a bracket or button. Using lasers for such treatment offers the advantages of no bleeding, less painful, and immediate fixing of the accessory [72, 73].

Insular areas of transient tissue hypertrophy can simply be removed with the diode laser. The diode laser is very beneficial for a number of isolated treatments, such as removing tissue that has disproportionate mini-screws, springs, and tools, as well as for compensating a tissue punch if required, when placing mini-screws in the unattached gingiva [74, 75]. Figure 5.18 shows this procedure using diode laser (980 nm).

5.7.4 Frenectomies

A laser-assisted frenectomy is a simple procedure that is best proposed after the diastema is closed as much as probable. Ankyloglossia can lead to problems with deglutition, speech, malocclusion, and periodontal problems. Frenectomies achieved

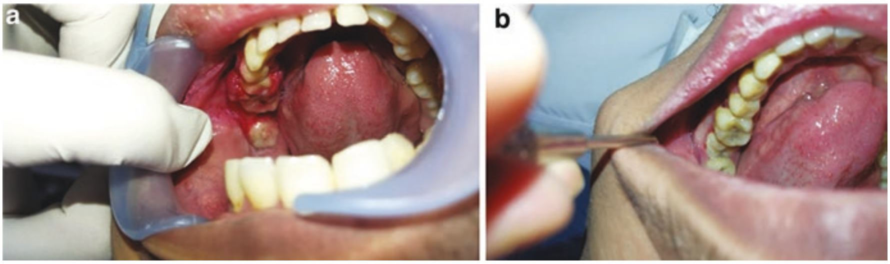

Fig. 5.18 Elimination of hyperplastic tissue using diode laser (980 nm). (**a**) Pretreatment. (**b**) After laser application

Fig. 5.19 (**a**) Mandibular anterior frenum impinging on attached gingiva, preoperative view. (**b**) Nd:YAG laser used to revise the frenal attachment, immediate postoperative view. Note good hemostasis and minimal thermal damage. (**c**) Two week postoperative view of surgical site with good healing

with laser favor excision of the frena painlessly, less bleeding, sutures, or surgical packing with no requirement for special postoperative care [76, 77]. Figures 5.19 and 5.20 demonstrate laser frenectomy procedures.

Lasers are also used for soft tissue retraction and its removal in restorative and implant dentistry. But the absorption characteristics of different lasers, and depth of penetration, play significant roles in treatment planning [78].

Prescription medications such as phenytoin and cyclosporine can cause fibrous gingival overgrowth, the removal of which can be accomplished by using the shorter wavelength lasers. This has minimal effects on enamel and cementum [79]. Conversely, removal of the gingival tissue to uncover an implant is best accomplished with the longer wavelength devices, such as erbium and carbon dioxide lasers, since their energy is absorbed on or near the surface. This prevents or minimizes heat buildup and transfer to the metallic implant fixture [72, 80].

5.8 Hard Tissue Applications

Argon laser (488 nm) provides high-intensity visible blue light, which is capable to initiate photopolymerization of light-cured dental materials such as composite resins resulting in a deeper cure and improved physical properties of the restorative

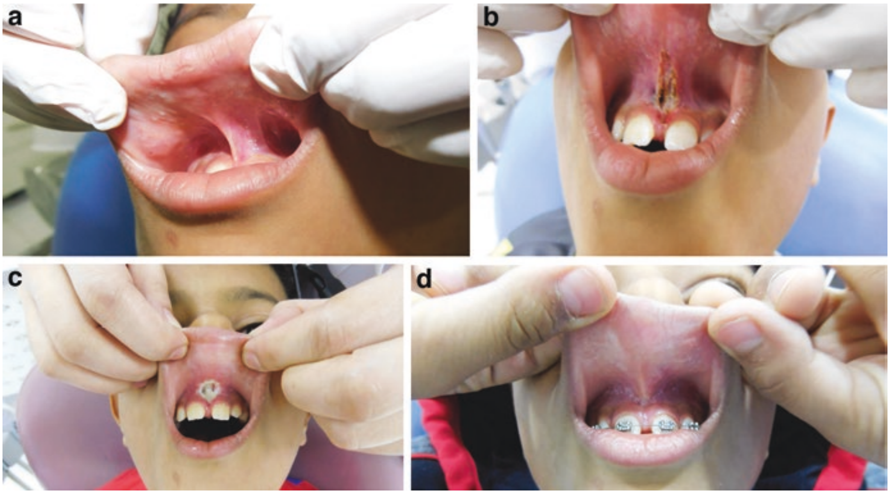

Fig. 5.20 Labial frenectomy using diode laser. (**a**) Before treatment. (**b**) After laser treatment. (**c**) After 5 days from laser treatment. (**d**) After 30 days

material. Argon laser emission is also effective to reconstruct the surface chemistry of both enamel and root surface dentine, which decreases the probability of recurrent caries [81].

Tooth discoloration is the change in color of teeth as compared with adjacent teeth. Bleaching of discolored teeth has become common and has decreased the need for more invasive treatment approaches [82]. Bleaching process, which involves the use of energy sources to increase the rate of release of bleaching radicals, can be accelerated by various laser wavelengths. Different lasers produce different wavelengths, hence not all lasers are suitable for bleaching as wavelengths absorbed, scattered, or transmitted through tooth structure can damage enamel, dentin and pulp [83, 84]. The bleaching impression relies on the specific absorption of a narrow spectral range of green light between 510 and 554 nm within the chelate compounds. Diode wavelengths (940 nm), for example, can also be used for bleaching with a different chemical catalyst [85]. The catalyst interacts with the light, whether visible or invisible to the human eye. $KTiOPO_4$, KTP, argon, and diode lasers can accomplish a positive outcome in office bleaching [86, 87].

5.9 Laser Fluorescence

Enamel demineralization with white spot forming on the buccal surfaces of the teeth is a comparatively common side influence from orthodontic treatment with fixed appliances. Studies have shown that such tiny areas of superficial enamel demineralization may remineralize.

5.10 Cavity Preparation, Caries, and Restorative Removal

Numerous studies describe the use of Er:YAG lasers, since 1988, for removing caries in the enamel and dentine by ablation, tooth preparation for a restoration, and removal of defective composite filling material (cement, composite resins, and glass ionomers). Figures 5.21 and 5.22 demonstrate an erbium laser for restorative dentistry.

Fig. 5.21 (**a**) An erbium laser with a glass tip beginning to remove a carious lesion. (**b**) The completed preparation with the enamel surface etched. (**c**) The finished restoration in place

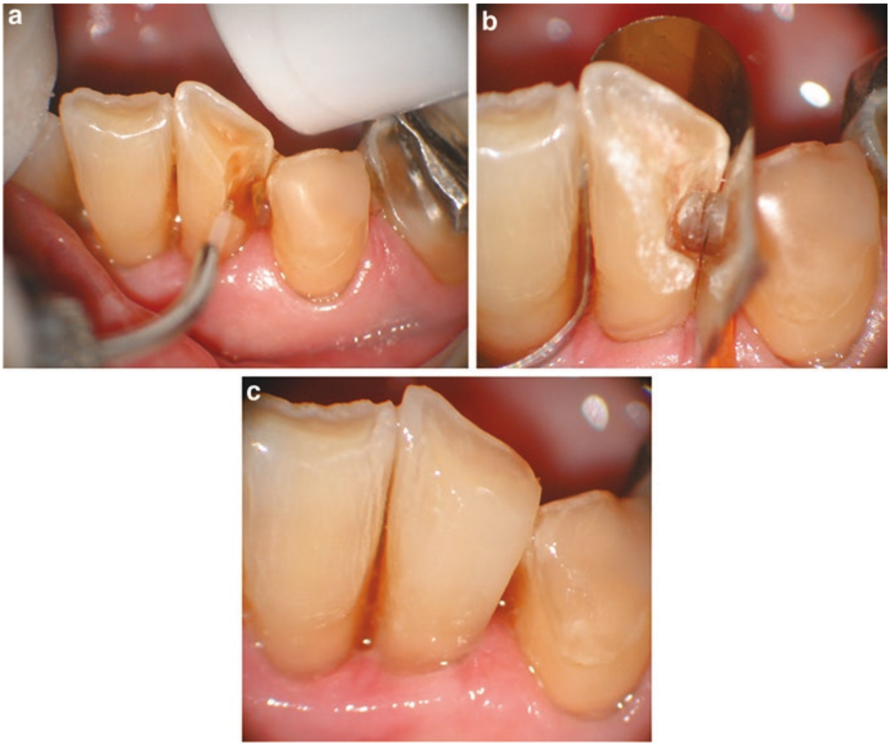

Fig. 5.22 (**a**) The erbium laser is aimed at the carious lesion. (**b**) The carious material is removed and the preparation completed. (**c**) The tooth is restored

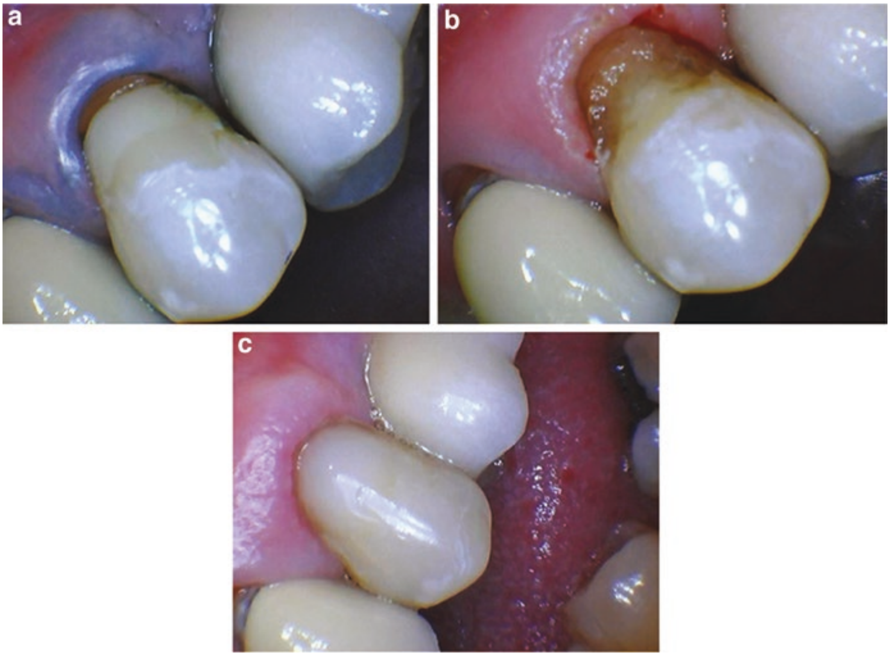

Fig. 5.23 (**a**) A preoperative view of a carious lesion extending apical to the existing inflamed marginal gingiva. (**b**) Shows the final preparation as well as the recontoured gingival tissue, both accomplished with the superpulsed 9300 nm carbon dioxide laser. (**c**) Depicts the final restoration and gingival contour

Carious tooth structure has higher water content than healthy enamel or dentin, so the laser would be able to interact selectively with the caries. On the other hand, if fluoride ions in the tooth structure have widely replaced hydroxyl groups, the laser energy must be increased to be effective [88]. The ablation mechanism of erbium lasers enhances the adhesion between the restorative material and the cavity. It also causes obliteration of the dentinal tubules [89]. However, removal of enamel and dentin by means of laser leads to thermal side effects. In contrast to this Er:YAG, superpulsed CO_2 laser and Er,Cr:YSGG lasers have advantage of reducing thermal effects [90, 91]. Figure 5.23 shows a restoration performed with the superpulsed CO_2 laser.

Clinicians should keep in mind that while using this type of laser for caries removal, cooling with water is indicated with no loss in laser intensity. Laser treatment is contact-free and has advantages over rotary instruments such as direct cooling of the area with water spray; absence of drilling sound, pressure, pain, temperature, and anesthesia can be omitted.

Laser etching has been assessed as an option to acid etching of enamel and dentine. Enamel and dentine surfaces etched with lasers expose micro-irregularities and no smear layer. CO_2, Nd:YAG, Er:YAG and the equivalent Er,Cr:YSGG laser are both an alternative for enamel conditioning and have proven to be more effective than phosphoric acid [92]. For etching with lasers, the surface is covered with accelerator and irradiated until the accelerator evaporates fully. Fracture of enamel is a common incident after ceramic brackets are detached from the tooth surface. This can be avoided by thermal detaching of brackets using CO_2 and YAG lasers [93, 94].

5.11 Treatment of Dentinal Hypersensitivity

Dentinal hypersensitivity is one of the numerous prevalent illnesses in clinical dental practices. Identification of the desensitizing influences of Er:YAG lasers with those of a traditional desensitizing system on cervically endangered hypersensitive dentine demonstrated a positive outcome than with other agents [95, 96].

5.12 Research

Lasers have been used for diagnostic and other research purposes as shown in Table 5.4**.**

5.13 3D Laser Scanner for E-Model Preparation

A laser scanner can be employed as a soft tissue scanner and is a priceless tool for its efficiency of treatment and formulation of 3D images of oral dental structures. There is no necessity of cast preparation as e-models are provided from scanned impressions. Images have been performed to establish databases for normative populations and cross-sectional growth changes and furthermore to estimate the clinical consequences in surgical and nonsurgical operations in the head and neck areas [97, 98].

Table 5.4 Laser applications used as research tools in dentistry

Laser type	Wavelength	Clinical application/research
Argon	488 and 515 nm	Detection of caries (laser fluorescence) Confocal microscopic imaging of soft and hard tissues Flow cytometric analysis of cells and cell sorting
Helium neon	633 nm	Scanning of phosphor plate radiographs Scanning of conventional radiographs for tele-radiology Profiling of tooth surfaces and dental restorations
Diode	633 nm 655 nm 670 nm	Laser Doppler flowmetry (LDF) to assess pulpal blood flow Detection of caries (laser fluorescence) Profiling of tooth surfaces and dental restorations Detection of subgingival calculus (laser fluorescence)
CO_2	10,600 nm	Detection of fissure caries by optical changes
Nd:YAG	1064 nm	Spectroscopic analysis of tooth structure Imaging of internal tooth structure
Er:YAG	2940 nm	Breakdown spectroscopic analysis of tooth structure

5.14 Benefits and Drawbacks of Dental Lasers

One of the main benefits of using dental lasers is its ability to accurately and precisely interact with target tissues. Lasers allows the clinician to achieve good hemostasis and reduce the need for sutures at the surgical site, during soft tissue procedures. There are less chances of metastasis associated with laser systems use and they also increase the chances of initial healing and rapid regeneration.

The hard tissue laser devices can selectively remove diseased tooth structure because a carious lesion has much higher water content than healthy tissue. In addition, use of lasers can minimize the need for anesthesia, while postoperative edema and scarring are markedly reduced. Osseous tissue removal and contouring proceed easily with the erbium family of instruments. Some of the other significant benefits to laser use are sterilization of the treatment site, relief of pain and anxiety for the patient, and laser exposure to enamel causes a reduction in caries activity.

There are some disadvantages to the current dental laser instruments. They are relatively high in cost and there is a need for additional training or qualified personnel. Although there are some laser tips that have side-firing capabilities, most of the laser energy is delivered in a circular spot at the end of the tip or handpiece. Because majorities of dental instruments are both side- and end-cutting, a modification of clinical technique will be required. Accessibility to the surgical area can sometimes pose a problem with the current available delivery system, and the clinician must prevent overheating the tissue. One additional drawback of the all tissue lasers is the inability to remove metallic restorations. Also, no single wavelength will optimally treat all dental disease.

5.15 Laser Safety

According to *The American National Standards Institute (ANSI),* lasers used in dentistry for bacterial decontamination or ablation techniques are considered to be class 4 lasers. This requires adequate control measures, laser safety officer (LSO), engineering controls, and training. The LSO is an individual who has been trained in laser safety, and does not necessarily have to be a clinician. That person provides all the necessary information, inspects, and maintains the laser and its accessories, and insures that all procedures for safety are carried out. All laser devices come with instructions on the safe use of the machine provided by the manufacturer. Clinicians using the laser devices should be aware of the fundamentals of laser physics.

Class 4 lasers are considered high-powered and can pose a hazard to the eye or skin from direct beam exposure. Protective eyewear for the patient and the entire surgical team along with proper clothing must be worn when the laser is under operation. The surgical environment should have a warning sign and limited access. High volume suction and normal infection control protocol must be followed. Use of screen and curtains should be promoted. The laser itself must be in good working order so that the manufactured safeguards prevent accidental laser exposure. Foot pedal control switch with protective hood prevents accidental depression by surgical staff.

The laser plume, also known as laser-generated air contaminates (LGAC,) is a visible or invisible biologic hazard of gas fumes created when the target tissue is ablated or vaporized. Proper management of laser plume is imperative as the laser plume has the ability to carry viruses, bacteria and other organisms that can be hazardous to the laser operator and assisting personnel. Use of laser filtration masks prevents airborne contamination.

Other important safety considerations include potential fire hazards and management of the laser plume. The fiber-optic tips should be steam sterilized. Combustible materials, such as alcohol, should never come in contact with the working beam of the laser and should be kept as far away as possible. Nitrous Oxide/Oxygen can be used in conjunction with a laser procedure as long as the scavenging system is operating properly.

5.16 Conclusion

Lasers technology for hard and soft tissue surgery application is at an extraordinary state of discrimination, having had individual decades of development, up to the modern time, and additional improvements can transpire. The field of laser-based photochemical reactions carries surpassing guarantee for supplementary applications, especially for targeting specific cells, pathogens, and molecules.

A moreover area of future germination is anticipated to be a unification of diagnostic and therapeutic laser techniques. Regarding the future, it is presumed that specific laser technologies will grow indispensable ingredients of contemporary dental patients beyond the next decade.

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