Potential of Lasers in the Realm of Aesthetic Dentistry: A Narrative Review

Ivaturi Sri Sai Meghana[1] Amitha Ramesh Bhat[1] Rahul Bhandary[1] Biju Thomas[1]

[1] Department of Periodontology, A B Shetty Memorial Institute of Dental Sciences, NITTE Deemed to be University, Mangalore, Karnataka, India

Address for correspondence Ivaturi Sri Sai Meghana, Postgraduate Student, A B Shetty Memorial Institute of Dental Sciences, NITTE Deemed to be University, Mangalore 575018, Karnataka, India (e-mail: saimeghana.5527@gmail.com).

J Health Allied Sci^{NU} 2023;13:313–322.

Abstract

In contemporary dental practice, patients' interests are taken into account in terms of function and appearance. The importance in everyday circumstances, current advertising, and the media in general highlight their effect on an attractive appearance. Many academics in the field of dental aesthetics have stated equivocally that when examining the impact of tooth appearance necessitates a multidisciplinary approach. Laser technology in cosmetic dentistry is in its early stages of development and has a lot of potential in the future. Also, with expanding use of lasers in clinical dentistry, treatment planning and prognosis will see a significant improvement in the future. The introduction of this technology has turned dentistry into a painless, bloodless field with increased predictability and instant outcomes. Furthermore, these techniques can help a cosmetic dentist regulate gingiva and osseous outlines with greater creativity in the pursuit of aesthetic dental principles with more efficient use of patient time. Even from the patient standpoint, the reduced requirement for suturing and faster healing times improves case acceptance and enables the increased demand for aesthetic dentistry. The resolution of this paper is to deliver an overview of various laser applications in aesthetic dentistry and its pros and cons over the conventional approaches.

Keywords

- photo-stimulation
- wavelength
- rehabilitation
- laser beam
- erbium lasers

Introduction

LASER is an acronym for 'Light Amplification by the Stimulated Emission of Radiation.' Dental lasers provide substantial contribution to the area of aesthetic dentistry, serving a meaningful resource for doctors performing all sorts of aesthetic procedures.[1] Clinicians in this particular sector not only aid patients in achieving attractive smiles and oral health but also in gaining enormous clinical benefits such as sterile surgeries and enhanced comfort levels.[2] When considering their early conceptions and the point in time when this progress could be implemented therapeutically with success, the similarities of lasers and aesthetic dentistry are comparable.[3]

Goldman et al pioneered the first laser into the domains of medicine and dentistry during the 1960s; however, the thermal damage was too high to regard this laser as a clinical device.[4] Following the development of the first Helium– Neon laser by W. R. Bennet and D. R. Herriott in 1961, Pick, a pioneer in the field of clinical periodontology, published on laser gingivectomy in 1985. A laser is a tool that converts light of various frequencies into chromatic emissions in the ultraviolet, visible, and infrared areas, among all waves in the spectrum are effective of mobilizing enormous heat and power when concentrated at close proximity. The beams produced by the laser are a specific sort of electromagnetic energy/radiation. The electromagnetic spectrum encompasses the complete range of

article published online
November 23, 2022

DOI https://doi.org/10.1055/s-0042-1758031.
ISSN 2582-4287.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

wave energy, spanning gamma rays with wavelengths of 10 to 12 m to radiowaves having wavelengths of thousands of meters.[5]

This review article is an effort to communicate the current role of lasers in aesthetic dentistry, trying to make some sense of recent claims and reports regarding aesthetic dentistry so that an understanding may begin to unfold.

Applications of Lasers in Various Esthetic Procedures

Lasers in Periodontology

Depigmentation

Laser ablation is among the most successful, comfortable, and dependable procedures for gingival depigmentation. Laser photon energy has been shown to be absorbed by tissue elements called chromophores. Chromophores in the oral tissue are composed of melanin, hemoglobin, allied pigmented proteins, hydroxyapatite, and scales.[6] Lasers have an electromagnetic spectrum of wavelengths and chromophores can absorb specific laser wavelengths.[7] When laser photon energy is absorbed into the water of the cells, the temperature of the water reaches the boiling point and produces a micro-explosion called water induced ablation.[8] High-power lasers are used for gingival depigmentation, the therapeutic effect of these lasers is thermal interaction as they produce heat and increase the kinetic energy of the affected tissue along with effects such as coagulation, vaporization, necrosis, carbonization, and denaturation of the tissue. High-power lasers have an output power of > 500 mW.[9] Different lasers have been used for gingival depigmentation including potassium–titanyl–phosphate (KTP), erbium and chromium doped, yttrium, scandium, gallium, garnet (Er, Cr:YSGG), Neodymium-doped yttrium, aluminum and garnet (Nd:YAG), diode, and carbon dioxide, (CO_2)[10,11] (►**Table 1**).

Gingival Cosmetic Re-sculpting

Critical concerns for patients in terms of smile aesthetics today include cosmetic dentistry principles such as gingival shape and contours, proportions of the teeth, and heights of the crown and hence laser utilization in soft tissue fits generally into the

Table 1 Different lasers used in gingival depigmentation procedures

KTP[79]	Solid	532 nm	Hgb, melanin	Pulsed/contact	**It enables implementation of accurate cuts with little cellular injury in the epithelium, comparable to those accomplished with a scalpel**
ERBIUM[80]	Solid	2790–2940 nm	Water, hydroxyapatite	Super-pulsed/ noncontact	It operates in a noncontact mode necessitating extreme accuracy and precision. However, they are quite sensitive, with Er:YAG lasers penetrating just 2–4 μm and Er:YSGG lasers penetrating only 15 μm
Nd:YAG[81]	Solid	1064 nm	Hgb, melanin	Pulsed/contact	It could penetrate water up to a depth of 60mm before being attenuated to 10% of its original intensity.
Ho:YAG[82]	Solid	2120 nm	Water, dentin	Pulsed/contact	Absorption is higher than that of Nd: YAG, and it is most typically employed in surgeries involving vascular anastomosis and temperomandibular joint disorders
Diode[83]	Solid	Infrared-810–980 nm blue/green–440/532 nm	Hgb, melanin	Continuous/grated pulse(not capable of free running pulse modes)/contact	Instead of water, high vacuum or cooling compressors are applied at 1 W at operative sites.
Argon[84]	Gas	488–514 nm	Hgb, melanin, resins	Pulsed/contact	The temperature within the tissue might significantly rise upon irradiation, and certain pulses make a highly apparent explosive sound owing to the bursting of vacuoles, which is referred as the “popcorn effect.”
CO_2[85]	Gas	9600–10,600 nm	Water, hydroxyapatite	Pulsed/grated	Most frequently used. The ’laser plume’ is generated when intracellular temperature and pressure trigger a cellular reaction as well as emission of vapor and cellular debris

Abbreviations: CO_2, carbon dioxide; Er, erbium; Er: Cr YSGG, erbium, chromium-doped yttrium, scandium, gallium and garnet; Er:YAG, erbium-doped yttrium aluminum garnet; Hgb, Hemoglobin b; Ho:YAG, holmium-doped yttrium aluminum garnet; KTP, potassium-titanyl-phosphate; Nd:YAG, neodymium doped yttrium aluminum garnet.

following categories: crown/height asymmetries rectification, gingival form and contour enhancement, tooth proportionality optimization, and crown lengthening.[12] Diode laser are usually applied at 0.8 to 1.2 W continuous mode with an advanced tip. Stabilization of gingival form and contour are key cosmetic dentistry principles that are critical to the final aesthetic outcomes of orthodontic treatment. The curvature of the gingival margins of the tooth is termed as gingival form and the gingival zenith of the maxillary lateral incisors and mandibular incisors should align with their longitudinal axis.[13] In contrast to the gingival form, gingival contour refers to a greater three-dimensional depiction of gingival topography. Sharp interdental papillae and evenly restored gingival margins at the cervical edges of the teeth indicate ideal gingival contour. A fascinating aspect of the clinician's learning curve is comprehending that the laser does not cut like a blade, but rather ablates the tissue utilizing incident photons at the fiber tip. The collimation coating protects the tip's sides, and none of the energy is transferred through the fiber's side. The correct strategy is not to squeeze the fiber, instead to drag it along the exact course intended and allow the highly focused laser energy to perform the task. Gingival contours refers to the thickness and shape of the margins of the gingiva to the crown of the tooth. Once a soft tissue gingivectomy incision is completed, the tip of the fiber is aimed at the rolling margin and beveled to the appropriate sharpness. The tooth appears considerably better 3 weeks following gingival shaping and contouring.[14]

Crown Lengthening

Crown lengthening is suggested in the management of aesthetic constraints, such as altered passive eruption, excessive gingival display-also described as gummy smile, or to promote the cosmetic results of final restorations.[14] While gingivectomy with or without osseous resective surgery is the most often used procedure for clinical crown lengthening, osseous surgery with an apically positioned flap, and laser-assisted gingivectomy are other alternatives.[15]

Different Lasers Used in Crown Lengthening

Dental lasers have quite a range of perks in CL treatments, including improved hemostasis, gingival sculpting, incision accuracy, and precision.[15] The duration between the CL surgery and the final restoration is one of the most consistent requested questions in clinical practice. It is advised that non-aesthetic parts recover in 6 to 12 weeks, while anterior aesthetic areas should heal in at least 6 months to account for probable gingival margin alterations. Procedures[16,17] (►**Table 2**).

Table 2 Different lasers used in crown lengthening surgeries

Laser	Properties
Diode	Primarily used for precise soft tissue ablation
Nd:YAG	Both soft and hard tissue removal
Erbium	Both soft and hard tissue removal
CO_2	Primarily used for sift tissue removal

Vestibuloplasty

Vestibuloplasty is a surgical therapy that involves modifying the soft tissue attachments upon the buccal, labial, and/or lingual portions of the residual ridges to deepen the oral vestibule.[18] Diode lasers are usually used. When the merits and demerits of competing treatment modalities for mechanical surgical operations are considered, minimally invasive laser-assisted soft tissue excision and ablation appear to be a highly appealing technique. The laser has a favorable influence on patients and the dental team owing to its numerous advantages. In comparison to traditional soft tissue surgery, Er:YAG laser aided vestibuloplasty is a minimally invasive procedure. The inclusion of the Er:YAG laser to the soft tissue excisional therapy regimen provides the dentist with a less distressing and greater beneficial treatment protocol than the earlier continuous wave diode or pulsed CO_2 laser.[19] Recent advances include Er;Cr:YSGG, in which wavelengths of 2780 nm, usually T4 tip, 400 µm diameter for soft tissue management and G6 tip, 6 mm long, 600 µm diameter for hard tissue management.

De-sensitization of Teeth

Dentinal hypersensitivity (DH) can be a major problem for periodontal patients who frequently have gingival recession and exposed root surfaces. Many studies provide information about the clinical effectiveness of Er:YAG, Nd:YAG, and diode lasers in the treatment of DH. Reductions in DH have been reported with the use of Er:YAG laser due to its action of evaporating the water in the dentition, which leads to degranulation or coagulation of the organic elements, causing their accumulation and blockage of dentinal tubules. However, potential problems exist with the mechanism of action of Er:YAG laser irradiation, as this laser can cause ablation of dentinal tubules rather than occluding them. Thus, the influence of different irradiation parameter on the dentin's morphology appears to be of extreme clinical importance (70 mJ/pulse and 20 Hz in non-contact mode).[20–22]

Several studies were performed to show the mechanism of the Nd:YAG laser irradiation in decreasing the DH. The power of the Nd:YAG is < 1.5 W, lasing can cause alterations such as melting of dentin and closure of exposed dentinal tubules, cracking, and fissuring on the root surface and when the power is > 1.5 W, changes such as cracks and fissures in dentin protein can be seen and the pulp may be injured.[23] It can be assumed that the dentin may be fused during Nd:YAG laser irradiation. Its effectiveness is probably due to an occlusion or narrowing of dentinal tubules, thereby blocking fluid flow across dentin. Recently, the diode laser was introduced in treating DH by inducing changes in neural transmission networks within the dental pulp, which may stimulate the normal physiologic cellular functions.[24,25]

In addition, these lasers stimulate the production of sclerotic dentin, thus promoting the internal obliteration of dentin tubules and diode lasers blocks the depolarization of C-fiber afferents.[26]

Photodynamic Therapy

Photodynamic therapy (PDT) is a powerful laser-initiated photochemical reaction, involving the use of a photo active dye (photosensitizer) activated by the light of a specific wavelength in the presence of oxygen. Application of PDT in periodontitis continue to evolve into a mature clinical treatment modality and is considered as a promising novel approach for eradicating pathogenic bacteria in periodontitis.[27]

Mechanism of Action

The three components of PDT are oxygen, photosensitizer, and light. When a photosensitizer is administered to the patient and irradiated with a suitable wavelength, it goes to an excited state from its ground state. This excited state can then decay back to its ground state or from the higher energy triplet state.[28] The triplet state photosensitizer can react with biomolecules in different pathways. The advantage of PDT over conventional treatments is based on its minimal invasiveness and selective tumor destruction, with the preservation of healthy tissues. PDT is also known to be an effective treatment modality for pre-malignant lesions and early-stage tumors of the head and neck region.[29]

Here, the aesthetic advantage to the patient is obvious, as the use of facial prosthesis present many psychological challenges for the patient. The preservation of facial structures means patient's quality of life will not be diminished as the ability of speech, eating, and other activities will not be compromised by PDT.[30]

Laser-assisted New Attachment Procedure

Laser-assisted new attachment procedure (LANAP) is a minimally invasive therapy for the treatment of periodontal disease through regeneration than resection. In concept, the LANAP protocol is rather simplistic. The ultimate goal is to set up the periodontal environment to promote self-regeneration of the lost attachment and osseous structure that result from periodontal disease (designed to use 1064 nm wavelength and 635 µ/sec “long pulse”).[31]

Aesthetic Advantages of LANAP

1. Scalpel surgery could result in possible attachment loss, gingival cratering, and gingival recession. By comparison, LANAP eliminates pockets with minimal recession or repositioning of the gingival margin.[32]
2. Laser troughing makes it possible to visualize and access the root surface by removing necrotic debris, releasing tissue tension and controlling bleeding. If also defines tissue margins before ultrasonic and mechanical instrumentation, preserves the integrity of the mucosa, and aids in maintaining the free gingival crest.

This technique allows for the selective removal of sulcular or pocket epithelium while preserving connective fibrous tissues.[31]

Lasers in Restorative Dentistry

Removal of Extrinsic Stains and Dental Bleaching

Aesthetic dental procedures have proven more popular in clinics as a result of greater public consciousness and current breakthroughs. Many procedures for dissolving external stains have been used conventionally, including micro or macro abrasion and hydrogen peroxide bleaching.[33] Extrinsic stains can become ’internalized’ into the outer layer of the dental enamel after extended exposure to certain substances, which enable bleaching more challenging.[34] The heat energy generated by laser activation is used to easily erase stains. Schoenly et al investigated the feasibility of removing internalized extrinsic stains on enamel utilizing a near UV laser (60 ns pulse rate). The stains were removed by the laser, leaving an enamel surface that was smooth and shiny. Furthermore, this procedure ablates any afflicted underlying enamel. Intrinsic stains are removed by photochemical and photothermal bleaching. For tooth bleaching, lasers such as KTP, CO_2, and diode are utilized.[35]

Indirect Restorations using CAD/CAM Lasers

An accurate impression is essential to restore missing teeth or dental tissues. Traditionally, hydrocolloid or rubber-based impression materials and a casting model/die are being used. Unfortunately, these materials have been associated to a variety of adverse effects including infection, dimensional changes, intolerance, and gagging, only in certain patients.[36] In the current scenario, lasers are deployed to scan the intraoral tissues to generate 3D digital impressions.[37] Two different types of lasers have been used Er:YAG at 2940 nm and Er;Cr:YSGG at 2780 nm and both are applied for 1 to 2 minutes.

The stereolithography technology, in addition to CAD/CAM, is performed for laser induced polymerization of resins in incremental layers and the fabrication of dental prostheses including temporary resin restorations. Lasers are also being utilized to melt fine layers of powder to develop restorations. Each layer's molten powder grains fuse together to produce a solid structural layer. Customized prostheses are produced by layering new layers on top of old ones. Selective laser melting, often known as laser sintering, is the name given to this procedure.[38]

Lasers in Prosthodontics

Management of Unsuitable/Undercut Alveolar Ridges

A mild undercut on both sides may allow the denture to retain, but a significant undercut on both sides may compromise the denture's stability and retention. Because expansion tooth sockets that are poorly closed by compression result in undercut alveolar ridges and natural undercuts are most typically visible in the lower anterior region or predominately in premaxillary regions, undercut areas should be surgically repaired before prosthesis fabrication.[39] CO^2, diode, Nd:YAG, and erbium family of lasers are applied for hard tissue surgery.

Resorption usually occurs when people age and their tooth structure deteriorates. Both vertical and lateral ridges were resorbed at the same time, establishing a homogeneous ridge. If there is a fluctuation in resorption, pointed bony spicules, poor dental hygiene, extraction, or loss of teeth at different times, hyperplastic tissue development, irregular gum massage or uneven ridges, rendering denture placement challenging.[40]

Formation of Ovate Pontic Sites

There are many causes of unsuitable pontic sites. Two of the most common causes are insufficient compression of alveolar plates after an extraction and nonreplacement of a fractured alveolar plate. Unsuitable pontic sites result in unaesthetic and non–self-cleansing pontic design. For favorable pontic design recontouring of soft and bony tissue may be needed. Soft tissue surgery may be performed with any of the soft tissue lasers and osseous surgery may be performed with erbium family of lasers. Also, granulation tissue should be eliminated before osseo-integrated implant installation, which is done by lasers.[41]

Veneer Removal

Lasers are used to dislodge restorations without damaging them. Laser energy passes through unaltered porcelain glass and is absorbed by molecules of water at the adhesive. Debonding involving silane and resin takes place without inflicting damage to the underlying tooth[42] as for the removal of undesirable or unsuccessful veneers, lasers such as Er: YAG, Er, Cr:YSGG are adopted.[43] The use of laser reduces the difficulty in removing restoration. The application of laser eliminates the need for cutting for cutting the crown while removing. This method enhances aesthetic debonding without causing any trauma to the tooth.

Laser Troughing

Laser can be used to create a trough around a tooth before impression making. Laser eliminates most of the challenging tasks such as the application of retraction cord is reduced by using laser to create a trough before taking an impression.[44] It also plugs blood vessels, allowing for coagulation, and reduces necessity of hemostatic drugs and electrocution. The most common laser employed for troughing is Nd:YAG, as it vaporizes the epithelium, which is attracted to the marginal finish line, which is only a transient trouble. The most important function of marginal finish line is to maintain the biological width as it acts as the termination point of tooth preparation and reduces postoperative problems.[45]

Soft Tissue Management Around Abutments

As an argon laser absorbs hemoglobin, it improves oral tissue vaporization and coagulation. The Argon laser is ideal for gingivectomy and gingivoplasty, essentially removing and reshaping of soft tissues surrounding the abutment teeth. Argon laser with 300 µm fiber and a power setting of 1.0 W, continuous wave delivery and fiber is inserted into the sulcus in contact with the tissue. In a sweeping motion, the fiber is moved around the tooth and it is important to contact the tip with the bleeding vessels. This soft tissue therapy around the abutment enables a better finish line and optimum crown length. It also improves troughing and allows for a more accurate impression, resulting in good fixed prosthesis performances.[46]

Soft Tissue Management Around Laminates

The application of an argon laser facilitates the recontouring and elimination of residual gingival tissues surrounding laminates. The laser can be used as a primary surgical instrument to remove excessive gingival tissue, whether diseased, secondary to drug therapy or orthodontic treatment. The laser removes the tissue and provide hemostasis around the wound.[46]

Lasers in Ortho-Aesthetic Enhancement

Lasers have typical implications in orthodontic practice, including enamel etching before bonding, tooth movement acceleration, pain relief following orthodontic force, avoidance of enamel demineralization, bone remodeling, and debonding of ceramic brackets.[47]

Laser Etching

Upon laser irradiation, physical transformations such as melting and recrystallization, proceed in enamel, resulting in the creation of many pores and bubble-like inclusions.[48] This procedure is analogous to orthophosphoric acid's type III pattern. As a result, laser irradiation is a viable substitute to traditional acid etching when etching enamel surfaces. Likewise, laser etching of enamel and dentin has been shown to produce a cracked, uneven surface as well as open dentin tubules, which is excellent for adhesion.[49]

Acid-resistant surfaces are produced through laser-etching techniques. Laser affects a few acid-soluble molecules, reduces the water and organic components and the calcium to phosphorous ratio, decreases the carbonate to phosphate ratio that results in the production of much more stable structure. In terms of mean shear bone strength, an Er, Cr: YSGG laser operating at 1 or 2 W for 15 seconds achieved results equivalent to acid etching.[50] With such a power of 1.5 W, the same laser and application timing resulted in significant etching for orthodontic bonding. Although 1.5 W and 2 W laser irradiation can be used instead of traditional acid etching, the 0.5, 0.75, and 1 W settings are incapable of etching acceptable enamel for orthodontic molar tube bonding.[51]

Ceramic Brackets Debonding

Clinicians often encounter fractures and cracks in the enamel and brackets during the removal of ceramic brackets. With the application of laser irradiation, the adhesive resin can be softened, allowing light force to be applied during debonding. An Nd:YAG laser applying at 2 J at 2 to 5 W/cm^2 for 3 seconds or more is effective during the removal of monocrystalline and polycrystalline ceramic brackets although it significantly decreases the bond strength to a greater extent for the polycrystalline ceramic brackets than for monocrystalline brackets.[52]

Laser Scanning

This is a 3D data capture system described by Arridge et al in 1985 and refined further by Moss et al in 1988. A video camera captures the reflected beam from a low-power Helium–Neon type II laser that is swept across the subject's face or body. The image may be saved and viewed on a computer, and it can be turned in any orientation. Laser scanning systems can often be used as soft tissue scanners as well. As a result, longitudinal examination of facial growth or the results of face surgery may now be evaluated by superimposing serial scans on a hard scan, resulting in a composite representation of the patient's soft and hard tissues. This aids in the investigation of several fascinating possibilities, notably in the fields of facial growth and facial surgery outcomes.[53]

Laser Holography

Holographs can be performed to capture 3D data and analyze stress in hard tissues that have been treated to varied loading forces. Even though holograms have been used to store 3D facial images, its primary record-keeping application is a replacement for orthodontic study casts. Study models have the benefit of being both accurate and inexpensive, but they also have the liability of being brittle and bulky. Holograms are similar to radiography or pictures in size and are extremely durable. White laser reflection holograms from study castings will necessitate a special camera (Holocam System 70 camera, Holofax Limited, Rotherwas, Hereford). He-Ne lasers at 633 nm at 50 mW are usually applied with very fast double pulse measured in nanoseconds. When holograms provide a 3D image, all parts of the occlusion cannot be seen from a single image. A baseline of four views are required for each set of study casts, including an occlusal view and three views in right buccal, left buccal, occlusion and frontal. These could be viewed using a specialized light box that enables for hologram viewing and calibration.

However, there are several issues, primarily related to the hologram's unfamiliarity and the truth that some images of the teeth are poor, notably in evaluating overbite and accurately assessing overjet.

The idea of 'reverse' holography is an intriguing advance. A hologram of a dental impression is developed, which is then inverted to create the appearance of a study cast without the need for plaster casting. Although a means of capturing the teeth in occlusion would be required, this might eliminate the requirement for pouring dental study casts entirely. Eventually, a device may be designed that could take holograms of the patient's teeth precisely even without requirement of study casts or dental impressions of any kind.[53]

Laser Welding

A laser's capacity to generate a power density higher than 106 W/cm^2 is a key aspect in determining its feasibility for welding. Given the narrow heat-affected zone (HAZ), laser beam welding produces narrow welds with monitored bead size and the galvanic effect is avoided because the weld is with the parent metal (self-welding), and welding very near to acrylic resin or ceramic is indeed conceivable without crack formation or harming the color.[54]

Popular modes include semiconductor lasers such as gas lasers, solid state lasers such as Er:YAG, Nd:YAG, Er:glass, Nd: glass, Cr:YAG, Ti:sapphire, Yb:YAG, Yb:glass, and diode lasers. This form of laser, which emits in the near infrared, has a wide range of emission power and excellent beam quality. Ti:Sapphire lasers may perform pulsed operation with quite short bursts.[55] The outcome of this procedure depends on the perfect combination of pulse energy of 6 to 14 J, a pulse duration of 10 to 20 ms, and peak power of 600 to 900 W.

Laser Specular Reflectance

Kusy et al dreamed up the laser specular reflectance configuration. They developed a manually controlled spectrometer to examine the surface textures of various dental materials. The majority of the beam is reflected back from the surface, and the strength of that reflection is detected by another detector positioned on a second rotary table controlled by its stepping motor. The signals generated by the photodetector are sent to a computer through a digital/analog processor, which controls the position of the second detector, angle of incidence, and stepping motors. Specular reflectance occurs only if the wire's surface is absolutely smooth, and the reflected intensity is monitored with the help of a photodetector.[56]

Lasers in Implant Management

Implant Recovery

The increased usage of dental implants has resulted in even increased number of failed implants and the need for therapy.[57] Failing implants may necessitate surgical removal utilizing approaches such as trephine osteotomy, block resection, and buccal bone ostectomy. These failing implants can be retrieved using an Er, Cr: YSGG laser, which enables a less invasive treatment than traditional methodologies. The Er, Cr:YSGG laser has been shown to cut bone successfully without melting, burning, or affecting the Ca:P ratio of the irradiated bone.[58] The cutting technique is based on incident light being intercepted by an air–water spray, which causes micro-explosions upon the targeted site. This hydrokinetic phenomenon results in clean cuts that are free of heat damage. The decontamination action of lasers may develop in the surrounding tissues and may assist uncomplicated tissue healing.[59] Diode lasers are used at 0.5 W and a hot tip is created before the laser application

Preparation of Surgical Template in the Implant Site

Pre-surgical planning is critical for obtaining both cosmetic and functional implants as well as several procedures are currently offered. Implant placement with surgical guidance is more precise than placement by free hand.[60] Prototyping strategies enable the fabrication of physical models from virtual computational simulations. Stereolithography (SLA)-fused deposition modeling and inkjet-based techniques are the current rapid prototyping methods in existence. SLA is a process that uses an ultraviolet laser to 'laser-cure' cross-sections of liquid resin and is often utilized for the fabrication of digital surgical guides. Patterns of SLS are opaque, whereas models of SLA are translucent. Several researchers have demonstrated that SLA fabrication of surgical templates benefits from great precision.[61] Er:YAG lasers are applied at 300 mJ, 35 Hz, and a pulse duration of 300 µs as well as diode lasers at 1.5 W in contact continuous mode at 9550 W/cm.[2]

Management of Periimplantitis

Peri-implantitis is a rapid progressive breakdown of osseointegration, in which bacterial toxins are produced, resulting in inflammatory responses and bone destruction.[59] The surface of the implant is potentially contaminated with soft tissue cells, bacteria, and additional bacterial metabolites in the event of peri-implantitis. Mechanical instrumentation between the implant threads renders it challenging to eliminate whole bacterial plaque and endotoxins. Debridement and degranulation of failed but also ailing implants can be performed using a non-injurious bone laser wavelength. Er:YSGG, CO_2 lasers, diode lasers, and were demonstrated to be successful for eliminating plaque and calculus from implant abutments without inflicting damage to their interfaces.[62] Despite their outstanding sterilizing properties, Nd:YAG lasers are inappropriate for use in the management of peri-implantitis because they produce an elevation in temperature as well as alterations on the implant surface.[63]

Laser Micropatterning of Dental Implants

In metals, laser peening, a type of cold working, creates a surface with compressive residual stresses, finer grain structures and improved hardness. This is accomplished through the use of precision laser micromachining on the implant surface, which results in a regulated surface roughness and has been found to encourage bone development at the surface. Laser peening can produce greater surface improvements than grit blasting.[64] Nd:YAG laser at 532 nm irradiation at 10 Hz is applied for the procedure

Laser Welding of Titanium Components

Laser welding can be used to develop strategic frameworks for implant prostheses to fit passively on multiple implants. This eliminates the casting methods and the implications of expansion-contracting throughout the framework's casting, as well as the nonpassivity.[65] Nd:YAG lasers at 1064 nm with the maximum output power of 1 KW is applied.

Lasers in Maxillofacial Rehabilitation

Maxillofacial rehabilitation to restore aesthetic form and functioning has always been demanding for maxillofacial surgeons. Three-dimensional scanning, a subset of additive manufacturing, is currently being used to improve the aesthetics of craniofacial prosthesis with accurate 3D construction.[66] It can construct not just intricate craniofacial mimics but also templates for intraoperative occlusal splints, bone grafts, osteotomy guides with increasing efficiency and simplified surgery. However, creating identical maxillofacial prosthetics remains a struggle even today.[67] Laser-based bioprinting, also known as Laser Induced Forward Transfer bioprinting (LIFT bioprinting), was developed over three decades ago by Bohandy et al[68] The benefits are high resolution and deposition of biomaterials in both solid and liquid forms, whereas the downsides include decreased cell viability, high cost, and cell injury.[69] GaAIAs (galium-aluminum-arsenide) at 780 to 890 nm. The SLS (selective laser sintering) is a CAD method. Lasers are used to design digital models and data are stored in STL formats using specific software, the data are again sectioned to thin slices (typically ~0.1 mm/0.004 inches)

Healing after Laser Therapy

Wound healing can be briefly divided into three phases: inflammatory, proliferative, and remodeling phases.

Inflammatory phase: Platelets, neutrophils, macrophages, and lymphocytes migrate to the wound.

Proliferation phase: Increase in fibroblasts and macrophages with a decrease in the acute-phase reactants.

Remodeling phase: Fibroblasts help re-create the extracellular matrix and deposit collagen.

Laser increases the fibroblast proliferation with no change in procollagen synthesis, increase in myofibroblasts (670 nm GaAIAs laser) and collagen deposition and decrease in fibroblast locomotion and increase in gingival fibroblasts (diode lasers with wavelength 670, 692, 780, 786 nm).[70] Noble et al noted a decrease in fibroblast locomotion in a 3D collagen lattice when the cells were exposed to He-Ne light.[71] 904 nm GaA found no difference in the expression of cytokines such as tumor necrosis factor (TNF)-α, interleukin (IL)-6, 8, E-selectin, intercellular adhesion-1, and vascular cellular adhesion molecule-1. Diode laser stimulate keratinocyte proliferation and endothelial cells, which may not be induced by self-expression of proangiogenic factors. He-Ne laser increases keratinocyte motility in vitro with no change in proliferation and differentiation during proliferative and remodeling phases of wound healing.[72]

Advantages and Disadvantages of Laser

Advantages

1. No anesthesia, no drill.
2. Less blood loss, less pain with hemostatic and analgesic effects.
3. Reduce postoperative edema.
4. Less postoperative scarring.
5. Early healing, rapid regeneration, reduce post sensitivity in restorations.
6. Dressing, suturing is not required for wound closure.
7. Less chances of metastasis.
8. Sterilization of treatment site—no infection.
9. Laser exposure to tooth enamel causes reduction in caries activity.
10. Patient becomes free of fear and anxiety.
11. Advantageous for medically compromised patients, since no medication is required such as antibiotics or pain-killers.

Disadvantages

1. Laser beam could injure the patient or operator. By direct beam or reflected light, causing retinal burns.
2. Laser—more expensive.
3. Need trained personal.

Laser Hazard Control Measures

1. The small flexible fiber optic, hand pieces or tip must be steam sterilized in sterilizing pouches.
2. Use of protective wear.
3. Use of screen and curtains should be promoted.
4. Use of proper clothing.
5. Use of anti-fire explosive.
6. Proper training and courses.
7. Use of laser filtration masks that prevents air borne contamination.
8. Foot pedal control switch with protective hood prevents accidental depression by surgical staff.[73]

Lasers	Advantages	Disadvantages
Gas lasers	1. Possess high affinity for water, rapid soft tissue removal 2. Quick hemostasis with shallow penetration	1. Possess the highest absorbance of any laser 2. Large size, high cost 3. Greater hard tissue destruction
Nd:YAG (solid state Laser)	1. Highly absorbed by pigmented tissues 2. Effective for cutting and coagulating dental soft tissues 3. Good hemostasis 4. Used in nonsurgical sulcular debridement	1. High cost and size
Erbium (solid state laser)	1. Erbium wavelength have a high affinity for hydroxyapatite and the highest absorption of water 2. Used for both soft and hard tissues	1. High cost 2. Slightly prolonged treatment time but better results
Diode (solid state laser)	1. Absorbed primarily by tissue pigments (melanin and hemoglobin) 2. Used for soft tissue applications	1. Poorly absorbed by the hydroxyapatite and water present in the enamel

Limitations of Lasers

It requires extra training and knowledge for clinical use and implementations. In addition to this, the high cost and technical investment are barriers. Multiple types of lasers are required in dental practice because different wavelengths are required for distinct operations.[73]

Effects on Dental Pulp

Elevated temperatures, such as 11°C, can produce irreparable pulpitis, whereas higher temperatures, such as 6°C, can induce pulpal necrosis. However, there is little disagreement in the literature about the pulpal damage caused by just laser thermal effects; some studies reported varying degrees of pulpal damage, while others found no significant evidence of pulpal alterations regardless of laser type or power configuration.[74]

Effects on Tooth Surfaces

Laser irradiation can also be imparted into the tooth surface. A considerable reduction in shear bond strength of brackets to teeth post bleaching with carbamide peroxide and diode has indeed been recorded. Despite Er:YAG laser irradiation with water and a pulse duration of 35 seconds did not lead to the formation of surface visible fissures, whereas it produced a 20% loss in dentin bending strength.[75]

Effects on Subcutaneous and Submucosal Layers

According to multiple reports, improper usage of dental lasers with air cooling spray may induce cervicofacial subcutaneous and mediastinal emphysema (CSE). Despite the fact that air pressure of an air turbine is higher than that of the instrument tip might be the causative factor for occurrence of CSE.[76]

Histopathological Changes of Laser

Photoacoustic and photochemical pathways are liable for other nonthermal tissue damage. They are characterized by single or recurring pulses of short duration. The ability of laser irradiation to trigger mutagenic alterations has been criticized; however, there have been no cases of laser-induced carcinogenesis so far. Deeper cell layers may be harmed by wavelength penetration. Persistent exposures to a low power density continuous wave Nd:YAG laser can result in inadvertent thermal necrosis.[77]

Infection Transmission due to Laser Smoke

As a byproduct of laser vaporization, a large volume of unpleasant smoke or plume is produced, especially by CO_2 lasers. Also, the viability or risk of viral exposure by laser smoke is still being debated. More than 600 chemical substances have been found in vaporized tissue plumes. Laser smoke byproducts include potentially harmful compounds such as free radicals, acetylene, formaldehyde, benzene, hydrogen cyanide, cresols, styrene, ethylene, methane, propylene, and toluene.[77]

Future Directions

Dentists continue to be pioneers in the advancement of laser applications for dental surgery. Laser wavelengths ranging from ultraviolet excimer lasers to far-infrared carbon dioxide lasers are currently being employed more frequently in dental research. Researchers may now demonstrate breakthroughs in photocoagulation, photoablation, and laser tissue welding by using new and evolving laser media. As laser media and miniatured delivery methods progress, dental laser research will continue to focus on the risk–benefit ratios and practicality of specific laser applications in improving patient aesthetics.[78]

Conclusion

This article discusses the numerous laser tools that are used in aesthetic therapies. Multiple wavelengths make it simple and accurate to perform hard tissue repairs as well as soft tissue excision and ablation. When adequate shape and function are attained with tissue biocompatibility, the aesthetic operation is successful; using a dental laser to execute the treatment provides a more favorable result.

Conflict of Interest
None declared.

References

1 Adams TC, Pang PK. Lasers in aesthetic dentistry. Dent Clin North Am 2004;48(04):833–860, vi

2 Coluzzi DJ. Fundamentals of dental lasers: science and instruments. Dent Clin North Am 2004;48(04):751–770, v

3 Saquib S, Jadhav V, Priyanka N, Perla N. Low level laser therapy in dentistry: a review. Int J Contemp Dent Med Rev 2014;2014:1–3

4 Goldman L, Hornby P, Solsman J. Design for Complete Medical Laser Laboratory, to be presented at 16th Annual Conference on Engineering in Medicine and Biology, Baltimore18, 1963

5 Verma SK, Maheshwari S, Singh RK, Chaudhari PK. Laser in dentistry: an innovative tool in modern dental practice. Natl J Maxillofac Surg 2012;3(02):124–132

6 Parker S. Verifiable CPD paper: laser-tissue interaction. Br Dent J 2007;202(02):73–81

7 Blayden J, Mott A. Soft-tissue Lasers in Dental Hygiene. John Wiley and Sons; 2013

8 Murthy MB, Kaur J, Das R. Treatment of gingival hyperpigmentation with rotary abrasive, scalpel, and laser techniques: a case series. J Indian Soc Periodontol 2012;16(04):614–619

9 Khalighi HR, Anbari F, Beygom Taheri J, Bakhtiari S, Namazi Z, Pouralibaba F. Effect of low-power laser on treatment of orofacial pain. J Dent Res Dent Clin Dent Prospect 2010;4(03):75–78

10 Kumar S, Bhat GS, Bhat KM. Development in techniques for gingival depigmentation–an update. Indian J Dent Res 2012;3 (04):213–221

11 Moshonov J, Stabholz A, Leopold Y, Rosenberg I, Stabholz A. Lasers in dentistry. Part B–Interaction with biological tissues and the effect on the soft tissues of the oral cavity, the hard tissues of the tooth and the dental pulp [article in Hebrew]. Refuat Hapeh Vehashinayim 2001;18(3-4): 21–28, 107–108

12 The Science and Art of Porcelain Laminate Veneers. J Prosthodont 2008;13(03):204–206

13 Rufenacht CR, Berger RP. Fundamentals of Esthetics. Chicago, IL: Quintessence Publishing Company; 1990

14 Sarver DM, Yanosky M. Principles of cosmetic dentistry in orthodontics: part 2. Soft tissue laser technology and cosmetic gingival contouring. Am J Orthod Dentofacial Orthop 2005;127(01):85–90

15 Nautiyal A, Gujjari S, Kumar V. Aesthetic crown lengthening using chu aesthetic gauges and evaluation of biologic width healing. J Clin Diagn Res 2016;10(01):ZC51–ZC55

16 Herrero F, Scott JB, Maropis PS, Yukna RA. Clinical comparison of desired versus actual amount of surgical crown lengthening. J Periodontol 1995;66(07):568–571

17 Lee EA. Esthetic crown lengthening: contemporary guidelines for achieving ideal gingival architecture and stability. Curr Oral Health 2017;4(02):105–111

18 Yilmaz E, Ozcelik O, Comert M, et al. Laser-assisted laterally positioned flap operation: a randomized controlled clinical trial. Photomed Laser Surg 2014;32(02):67–74

19 Pick RM, Colvard MD. Current status of lasers in soft tissue dental surgery. J Periodontol 1993;64(07):589–602

20 Watanabe H, Kataoka K, Iwami H, Shinoki T, Okagami Y, Ishikawa I. In vitro and in vivo studies on application of erbium: YAG laser for dentine hypersensitivity. Int Congr Ser 2003;1248: 455–457

21 de Carvalho RC, de Freitas PM, Otsuki M. de P Eduardo C, Tagami J. Influence of Er: YAG laser beam angle, working distance, and energy density on dentin morphology: an SEM investigation. J Oral Laser Appl 2005;5(04):245

22 Keller U, Hibst R. Ultrastructural changes of enamel and dentin following Er: YAG laser radiation on teeth. Laser Surg 1990; 1200:408–415

23 Lan WH, Liu HC, Lin CP. The combined occluding effect of sodium fluoride varnish and Nd:YAG laser irradiation on human dentinal tubules. J Endod 1999;25(06):424–426

24 Corona SA, Nascimento TN, Catirse AB, Lizarelli RF, Dinelli W, Palma-Dibb RG. Clinical evaluation of low-level laser therapy and fluoride varnish for treating cervical dentinal hypersensitivity. J Oral Rehabil 2003;30(12):1183–1189

25 Tengrungsun T, Sangkla W. Comparative study in desensitizing efficacy using the GaAlAs laser and dentin bonding agent. J Dent 2008;36(06):392–395

26 Wakabayashi H, Hamba M, Matsumoto K, Tachibana H. Effect of irradiation by semiconductor laser on responses evoked in trigeminal caudal neurons by tooth pulp stimulation. Lasers Surg Med 1993;13(06):605–610

27 Wilson M. Photolysis of oral bacteria and its potential use in the treatment of caries and periodontal disease. J Appl Bacteriol 1993; 75(04):299–306

28 Ochsner M. Photodynamic therapy in squamous cell carcinoma. J Photochem Photobiol B 2001;52:42–48

29 Konopka K, Goslinski T. Photodynamic therapy in dentistry. J Dent Res 2007;86(08):694–707

30 Philipp-Dormston WG. Photodynamic therapy for aesthetic-cosmetic indications. Giornale Italiano di Dermatologia e Venereologia: Organo Ufficiale. Societa Italiana Dermatol Sifilografia 2018;153(06):817–826

31 Gold SI, Vilardi MA. Pulsed laser beam effects on gingiva. J Clin Periodontol 1994;21(06):391–396

32 Kaldahl WB, Kalkwarf KL, Patil KD, Dyer JK, Bates RE Jr. Evaluation of four modalities of periodontal therapy. Mean probing depth, probing attachment level and recession changes. J Periodontol 1988;59(12):783–793

33 Joiner A. The bleaching of teeth: a review of the literature. J Dent 2006;34(07):412–419

34 Tantbirojn D, Douglas WH, Ko CC, McSwiggen PL. Spatial chemical analysis of dental stain using wavelength dispersive spectrometry. Eur J Oral Sci 1998;106(05):971–976

35 Schoenly JE, Seka W, Featherstone JD, Rechmann P. Near-UV laser treatment of extrinsic dental enamel stains. Lasers Surg Med 2012;44(04):339–345

36 Harashima T, Kinoshita J, Kimura Y, et al. Morphological comparative study on ablation of dental hard tissues at cavity preparation by Er:YAG and Er,Cr:YSGG lasers. Photomed Laser Surg 2005;23 (01):52–55

37 Ireland AJ, McNamara C, Clover MJ, et al. 3D surface imaging in dentistry - what we are looking at. Br Dent J 2008;205(07): 387–392

38 van Noort R. The future of dental devices is digital. Dent Mater 2012;28(01):3–12

39 Durrani S. Laser and it's application in prosthetic dentistry. Int J Dent Med Res 2015;1(06):183–188

40 Hansson S, Halldin A. Alveolar ridge resorption after tooth extraction: a consequence of a fundamental principle of bone physiology. J Dent Biomech 2012;3:1758736012456543

41 Nachrani P, Srivastava R, Palekar U, Choukse V. Lasers in prosthodontics: a review. NJDSR 2014;1:74

42 Nagaraj KR. Use of lasers in prosthodontics: a review. Int J Clin Dent 2012;5(01):91–112

43 Baidey SK, Singhal MK, Kumar A, Nair C, Tripathi S. Uses of lasers in prosthodontics. J Dent Sci Oral Rahabil. 2015;6:125–127

44 Lukram A, Sachdeva N, Kush Sahu A. Application of laser in prosthetic dentistry: A. Int J Dent Med Res 2014;1(04):100

45 Malhotra R, Thukral H. Laser applications in prosthodontics: a review. Int J Enhanc Res Med Dent Care 2016;3:20–25

46 Kalra T, Magrath M, Kalra G. Lasers in prosthodontics–part I implantology. Int J Laser Dent 2014;4:49–53

47 Nalcaci R, Cokakoglu S. Lasers in orthodontics. Eur J Dent 2013;7 (Suppl 1):S119–S125

48 Zakariasen KL, MacDonald R, Boran T. Spotlight on lasers. A look at potential benefits. J Am Dent Assoc 1991;122(07):58–62

49 Silverstone LM, Saxton CA, Dogon IL, Fejerskov O. Variation in the pattern of acid etching of human dental enamel examined by scanning electron microscopy. Caries Res 1975;9(05):373–387

50 Lee BS, Hsieh TT, Lee YL, et al. Bond strengths of orthodontic bracket after acid-etched, Er:YAG laser-irradiated and combined treatment on enamel surface. Angle Orthod 2003;73(05): 565–570

51 Berk N, Başaran G, Ozer T. Comparison of sandblasting, laser irradiation, and conventional acid etching for orthodontic bonding of molar tubes. Eur J Orthod 2008;30(02):183–189

52 Hayakawa K. Nd: YAG laser for debonding ceramic orthodontic brackets. Am J Orthod Dentofacial Orthop 2005;128(05): 638–647

53 Roberts-Harry D. Lasers in orthodontics. Br J Orthod 1994;21(03): 308–312

54 Jain S, Vibhute PK, Patil C, Umale V, Kulshrestha R, Chandurkar K. Laser welding in orthodontics: a review study. J Dent Health Oral Res 2020;1:1–4

55 Li L. The advances and characteristics of high-power diode laser materials processing. Opt Lasers Eng 2000;34(06):231–253

56 Bourauel C, Fries T, Drescher D, Plietsch R. Surface roughness of orthodontic wires via atomic force microscopy, laser specular reflectance, and profilometry. Eur J Orthod 1998;20(01): 79–92

57 Levin L. Dealing with dental implant failures. Refuat Hapeh Vehashinayim 2010;27(01):6–12

58 Kimura Y, Yu DG, Fujita A, Yamashita A, Murakami Y, Matsumoto K. Effects of erbium,chromium:YSGG laser irradiation on canine mandibular bone. J Periodontol 2001;72(09):1178–1182

59 Muroff FI. Removal and replacement of a fractured dental implant: case report. Implant Dent 2003;12(03):206–210

60 Park C, Raigrodski AJ, Rosen J, Spiekerman C, London RM. Accuracy of implant placement using precision surgical guides with varying occlusogingival heights: an in vitro study. J Prosthet Dent 2009;101(06):372–381

61 D'souza KM, Aras MA. Applications of computer-aided design/computer-assisted manufacturing technology in dental implant planning. J Dent Implant 2012;2(01):37

62 Mombelli A. Etiology, diagnosis, and treatment considerations in peri-implantitis. Curr Opin Periodontol 1997;4:127–136

63 Kreisler M, Kohnen W, Marinello C, et al. Bactericidal effect of the Er:YAG laser on dental implant surfaces: an in vitro study. J Periodontol 2002;73(11):1292–1298

64 Giannelli M, Bani D, Tani A, et al. In vitro evaluation of the effects of low-intensity Nd:YAG laser irradiation on the inflammatory reaction elicited by bacterial lipopolysaccharide adherent to titanium dental implants. J Periodontol 2009;80(06):977–984

65 Peyre P, Scherpereel X, Berthe L, et al. Surface modifications induced in 316L steel by laser peening and shot-peening. Influence on pitting corrosion resistance. Mater Sci Eng A 2000;280 (02):294–302

66 Bergendal B, Palmqvist S. Laser-welded titanium frameworks for fixed prostheses supported by osseointegrated implants: a 2-year multicenter study report. Int J Oral Maxillofac Implants 1995;10 (02):199–206

67 Keyhan SO, Ghanean S, Navabazam A, Khojasteh A, Iranaq MH. Three-dimensional printing: a novel technology for use in oral and maxillofacial operations. In: A Textbook of Advanced Oral and Maxillofacial Surgery; Volume 3;2016

68 Bohandy J, Kim BF, Adrian FJ. Metal deposition from a supported metal film using an excimer laser. J Appl Phys 1986;60(04): 1538–1539

69 Derakhshanfar S, Mbeleck R, Xu K, Zhang X, Zhong W, Xing M. 3D bioprinting for biomedical devices and tissue engineering: A review of recent trends and advances. Bioact Mater 2018;3(02): 144–156

70 Pereira AN, Eduardo CdeP, Matson E, Marques MM. Effect of low-power laser irradiation on cell growth and procollagen synthesis of cultured fibroblasts. Lasers Surg Med 2002;31(04):263–267

71 Noble PB, Shields ED, Blecher PD, Bentley KC. Locomotory characteristics of fibroblasts within a three-dimensional collagen lattice: modulation by a helium/neon soft laser. Lasers Surg Med 1992;12(06):669–674

72 Bouma MG, Buurman WA, van den Wildenberg FA. Low energy laser irradiation fails to modulate the inflammatory function of human monocytes and endothelial cells. Lasers Surg Med 1996;19 (02):207–215

73 Andersen K. Safe use of lasers in the operating room-what perioperative nurses should know. AORN J 2004;79(01):171–188

74 von Fraunhofer JA, Allen DJ. Thermal effects associated with the Nd/YAG dental laser. Angle Orthod 1993;63(04):299–303

75 Staninec M, Meshkin N, Manesh SK, Ritchie RO, Fried D. Weakening of dentin from cracks resulting from laser irradiation. Dent Mater 2009;25(04):520–525

76 Mitsunaga S, Iwai T, Kitajima H, et al. Cervicofacial subcutaneous emphysema associated with dental laser treatment. Aust Dent J 2013;58(04):424–427

77 Singh S, Gambhir RS, Kaur A, Singh G, Sharma S, Kakar H. Lasers A review of safety essentials. J Dent 2012;3(03):91–96

78 Colvard MD, Pick RM. Future directions of lasers in dental medicine. Curr Opin Periodontol 1993:144–150

79 Romeo U, Palaia G, Del Vecchio A, et al. Effects of KTP laser on oral soft tissues. An in vitro study. Lasers Med Sci 2010;25(04):539–543

80 Azzeh MM. Treatment of gingival hyperpigmentation by erbium-doped:yttrium, aluminum, and garnet laser for esthetic purposes. J Periodontol 2007;78(01):177–184

81 Atsawasuwan P, Greethong K, Nimmanon V. Treatment of gingival hyperpigmentation for esthetic purposes by Nd:YAG laser: report of 4 cases. J Periodontol 2000;71(02):315–321

82 Romanos GE, Nentwig GH. Present and future of lasers in oral soft tissue surgery: clinical applications. J Clin Laser Med Surg 1996; 14(04):179–184

83 Gupta G. Management of gingival hyperpigmentation by semi-conductor diode laser. J Cutan Aesthet Surg 2011;4(03):208–210

84 Trelles MA, Verkruysse W, Seguí JM, Udaeta A. Treatment of melanotic spots in the gingiva by argon laser. J Oral Maxillofac Surg 1993;51(07):759–761

85 Wigdor HA, Walsh JT Jr, Featherstone JD, Visuri SR, Fried D, Waldvogel JL. Lasers in dentistry. Lasers Surg Med 1995;16(02): 103–133