Chapter 2

Laser Dental Treatment Techniques

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Additional information is available at the end of the chapter

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Abstract

Dental laser technologies are one of the most rapidly developing areas in the modern technology. When the laser was discovered in the 1960s, it was classified as a solution in search of a problem, and today, laser technology is applied in many different areas. It basically remained a field of research. Typically in the most frequent dental surgery, the caries therapy was frequently compared to most types of lasers; the conventional mechanical drills are still superior, particularly CW or long-pulse lasers. Only laser systems capable of providing ultrashort pulses might be an alternative to mechanical drills. The number of laser applications is enormous, and it is not possible to explain all of them here. In this chapter, the development of suitable application units for laser radiation and other topics of interest in dentistry including laser treatment of soft tissue as well as laser welding of dental bridges and dentures are discussed. In some of these areas, research has been very successful. However, many clinical studies and extensive engineering effort still remain to be done in order to achieve satisfactory results.

Keywords: dental laser, dentistry, tissue interaction, radiation, wavelength

1. Introduction

1.1. Review of laser physics and tissue interaction

LASER is an acronym for light amplification by stimulated emission of radiation, which is based on theories and principles first put forth by Einstein in the early 1900s [1]. Laser light has a single wavelength. The production of lasing occurs when an excited atom is stimulated to release a photon before it occurs spontaneously. The spontaneous emission results in random light waves alike to light emitted by a light bulb [2]. The stimulated emission of photons produces a very coherent, collimated, and monochromatic radiation that is found nowhere else in nature [3]. Because laser radiation is so concentrated and focused, it may have an effect on target tissue at a much lower energy level than the other light sources [4]. The effects of laser radiation on the target tissue are dependent on its wavelength, power, and spot size

Laser type	Wavelengths	Delivery systems	Applications
CO_2	10,600 nm	Pulse or continuous wave	1. Soft tissue ablation 2. Gingival contouring for esthetic purposes 3. Treatment of oral ulcerative lesions 4. Frenectomy and gingivectomy 5. Elimination of necrotic epithelial tissue during regenerative periodontal surgeries
Nd:YAG	1064 nm	Pulse	6. Root canal therapy: helps eliminate pathogenic microorganisms and debris from the root canal 7. Extensive periodontal surgery and scaling to eliminate necrotic tissues and pathogenic microorganisms 8. Caries removal
Er:YAG	2940 nm	Pulse	9. Caries removal 10. Cavity preparation in enamel and dentin 11. Root canal preparation
Er,Cr:YSGG	2780 nm	Pulse	12. Enamel etching 13. Caries removal 14. Cavity preparation 15. Bone ablation without overheating, melting, or changing the calcium and phosphorus ratios 16. Root canal preparation
Argon	572 nm	Pulse or continuous wave	17. Polymerization of restorative resin materials 18. Tooth bleaching 19. Elimination of necrotic tissue and gingival contouring 20. Treatment of oral lesions such as recurrent aphthous ulcers or herpetic lesions 21. Frenectomy and gingivectomy
Diode	810–980 nm	Pulse or continuous wave	22. Proliferation of fibroblasts and enhancing the healing of oral lesions or surgical wounds 23. Frenectomy and gingivectomy 24. Correcting the gingival contouring for esthetic purposes
HO:YAG	2100 nm	Pulse	25. Gingival contouring 26. Treatment of oral lesions 27. Frenectomy and gingivectomy

Table 1. Lasers types, wavelengths, and their dental applications.

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which is determined by the laser device [5]. If the laser radiation comes into contact with the tissue, it can reflect, scatter, absorbed, or be transmitted to the other surrounding tissues. In the biological tissue, the absorption of laser radiation occurs because of the presence of free water molecules, proteins, pigments, and even other organic matters [6, 7]. Thermal interactions caused by the laser radiation, the water molecules, and their absorption coefficient perform a strong role [1]. Laser beams (*Er,Cr:YSGG*, *Er:YAG*) are well absorbed by water which are able to mechanically ablate enamel, dentin, and alveolar bone, while laser beams (*diode*, *Nd:YAG*, CO_2) are not well absorbed by water, resulting in strong thermal reactions, such as carbonization, charring, and melting of organic tissue [8, 9].

1.2. Review of modern laser technology accessible in dentistry

The first investigation of using the laser in dentistry was within the surrounding hard tissue, such as cavity preparation and caries removal as a replacement for the conventional drill. The ruby laser that was the focus of this investigation was invented in 1960 [10]. In succeeding years, many researchers examined the hard-tissue applications of the laser by using different types of lasers such as Ar, CO_2, and Nd:YAG. However, some studies resulted in major thermal damage to enamel and dentin [11], while other researchers concentrated their attention on the laser applications on soft tissue of these early generation high-powered lasers. It was determined that the CO_2 and the Nd:YAG lasers were capable of excellent soft tissue ablation and hemostasis [12]. These studies enabled the periodontists to use these lasers for soft-tissue treatment, such as gingivectomies and frenectomies [13, 14]. Despite, these early studies profound a thermal effect on target tissues, including gingiva, periodontal ligament, cementum, and alveolar bone, that their using for periodontal hard tissue was not promising. Within the 1990s, the Nd:YAG laser was included that had a flexible and fiber-optic delivery system, which made it appropriate for periodontal pocket, including the root surface debridement and pocket curettage [15, 16].

Researchers concluded that the Er:YAG laser, which is highly absorbed by water and hydroxyapatite, had an effect in enamel cutting [17, 18]. Subsequently, Eversole and others published numerous distinguished researches on the Er,Cr:YSGG laser and its effectiveness in soft tissue application (enamel, dentin, and bone), which all play a significant performance in periodontal [19, 20].

Because of this versatility, the Er,Cr:YSGG laser was the first all-in-one laser that made an economics of providing a laser treatment and more feasible for the periodontist and general practitioner [21]. Over the time, the collective research has resulted in a laser that has a real and beneficial application for periodontal care. Laser types, wavelengths, and their applications are listed in **Table 1**.

2. Dental laser systems and the basics of the work

2.1. Basic processes of laser radiation and tissue interaction

One of the main difficulties of all starting dental laser using is the depth of penetration of laser to the tissue and its effects on the principal constituents of the tissue. In order to clarify these questions, it is necessary to consider the process of light penetration in the tissue and the biological effects on the tissue [9, 22].

The process of laser penetration in the biological tissues is extremely complicated. This was connected to others with their nonhomogeneous structure. From the dental point of view, it is very necessary to deliver precisely a respective dosage of laser energy to a given tissue [2, 20].

This energy will be absorbed and transformed into other forms of energy. The laser passing through the upper layers of the tissue is reflected, scattered, and partially absorbed [23]. A degree of these processes is dependent upon tissue type and in the case of the epidermis. It can differ from the case of the skin or oil gland irradiation. In order to define the tissue laser radiation interaction, some considerations should be addressed with respect to the physical parameters and the structural features of the irradiated tissue [10, 12]. The absorption limit and its width are conditional upon the tissue structure, water, hemoglobin, enamel, dentin, pulp cavity, etc. [24].

Anyhow, the process of laser tissue radiation interaction is determined by the wavelength, power, and the irradiation time. The primary characteristics of this interaction are illustrated in **Figures 1** and **2**. **Figure 1** shows the primary physical phenomena, transmission, reflection, scattering, and absorption which occur including the biological tissue.

If there are two materials, one is white and the second black, in the sunlight, the white body will reflect more light waves than the black one and it will be cooler than the black body, which absorbs more solar energy. The radiation of the tissue involves the release of these four processes simultaneously [11, 25].

The transmission and the absorption of the laser in the given tissue are dependent, apart from its wavelength, and upon its power, it is not dependent on irradiation time. The spot size of the laser beam and its intensity will be the same regardless of how long this laser is on [26].

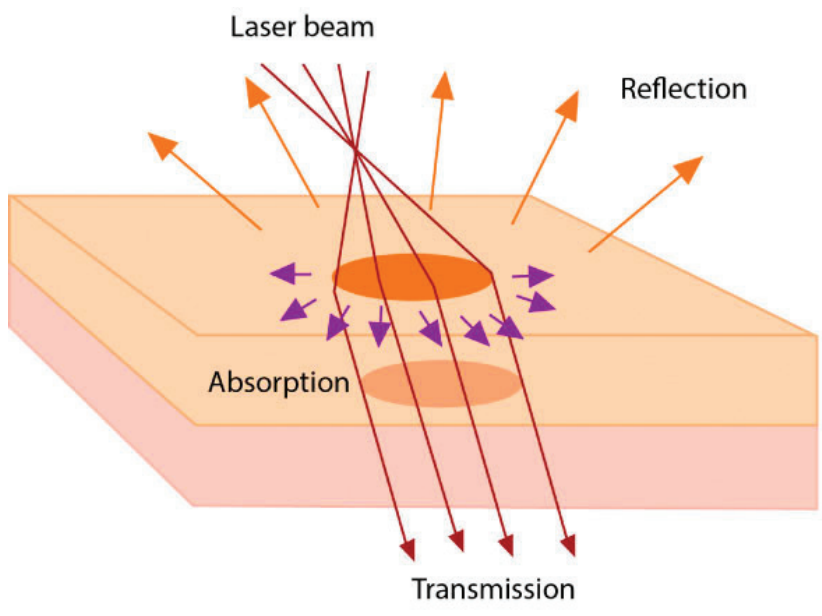

Figure 1. Illustration of the basic phenomena always accompanying the light-tissue interaction [28].

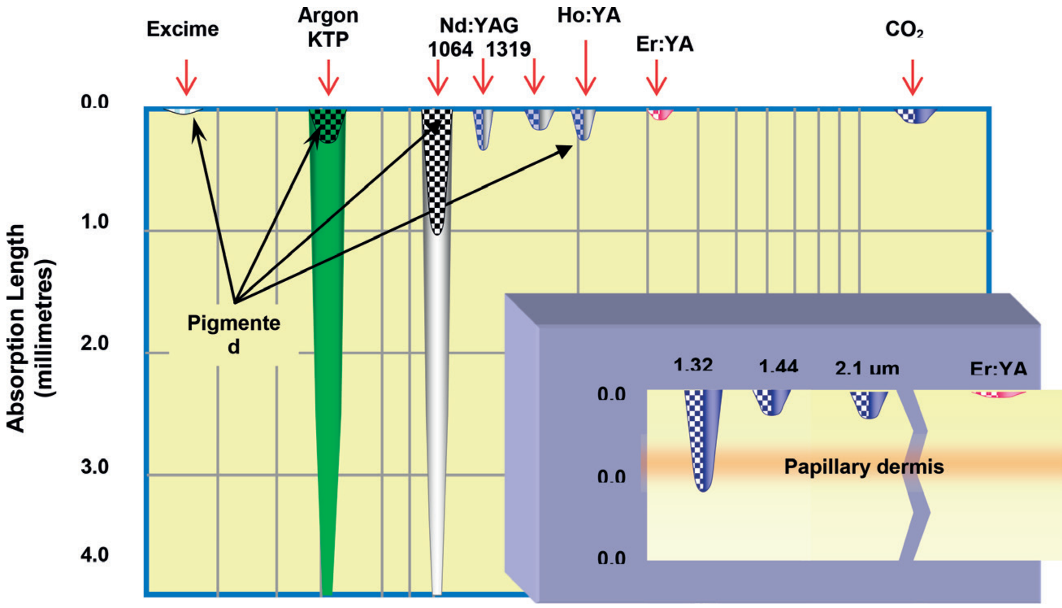

Figure 2. Transmission values of the main wavelengths for selected parts of the skin.

For example, the laser source with an output power of 30 mW emits 10^{16} photons per second. Theoretically, that means 10^{16} photons penetrate in the tissue every second [15]. Accordingly, it does not matter if a given point is irradiated for 1 second or for 1 minute. The alike situation occurs when we shine a given point on the wall with an electric torch [1, 5, 27].

The point is to select the wavelengths in bands where the processes of effective transmission in tissues for biostimulation purposes are predominant as well as for cutting, coagulation, defects, etc.

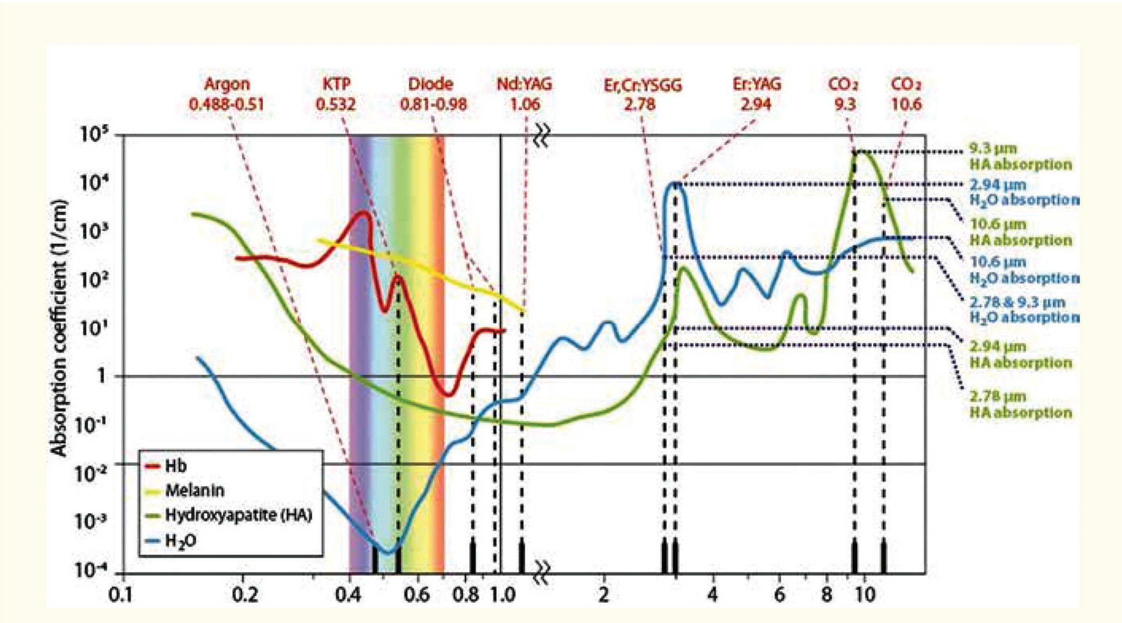

Figure 3. Characteristic of absorption of the laser light for the main tissue components [13].

Figure 2 shows in detail the transmission of the major important laser wavelengths in particular constituents of the skin tissue, while **Figure 3** illustrates the optical absorption characteristics of water, hemoglobin, and melanin and shows precisely the primary constituents of the tissue where absorption covers 100%.

Figure 4 displays the curves of the absorption by the principal components of teeth tissues and laser wavelengths. The biggest absorption occurs with wavelength of approximately 2900 nm. This is the radiation generated by Er:YAG laser and CO_2 laser radiation—10,600 nm ranks second, respectively. The abovementioned dependence for particular tooth tissues.

The time duration of treatment session on a given point is significant since it determined the total number of the photons penetrated in the tissue [25]. Photons emitted by laser source do not penetrate into deeper tissue layers even if a given point is irradiated for a longer time [5, 29]. If we mention the above example with the electric torch, we can see that the laser beam will not reach further and it is not more intensive, no matter whether the laser is on for an hour or for a minute.

In spite of this explanation, the treatment effect is obtained in a deeper layer after the long period of laser irradiation. This phenomenon occurring is similar to the exponential dependence between the transmitted energy (total number of photons transmitted during a therapeutic session) and the depth of penetration [3, 29].

The relation between the time duration of a treatment session and therapeutic effects can be explained by the penetrating photons that initiate the chain reaction which transfers the biological effects of the therapeutic session to the deeper tissue layers and at sides [30].

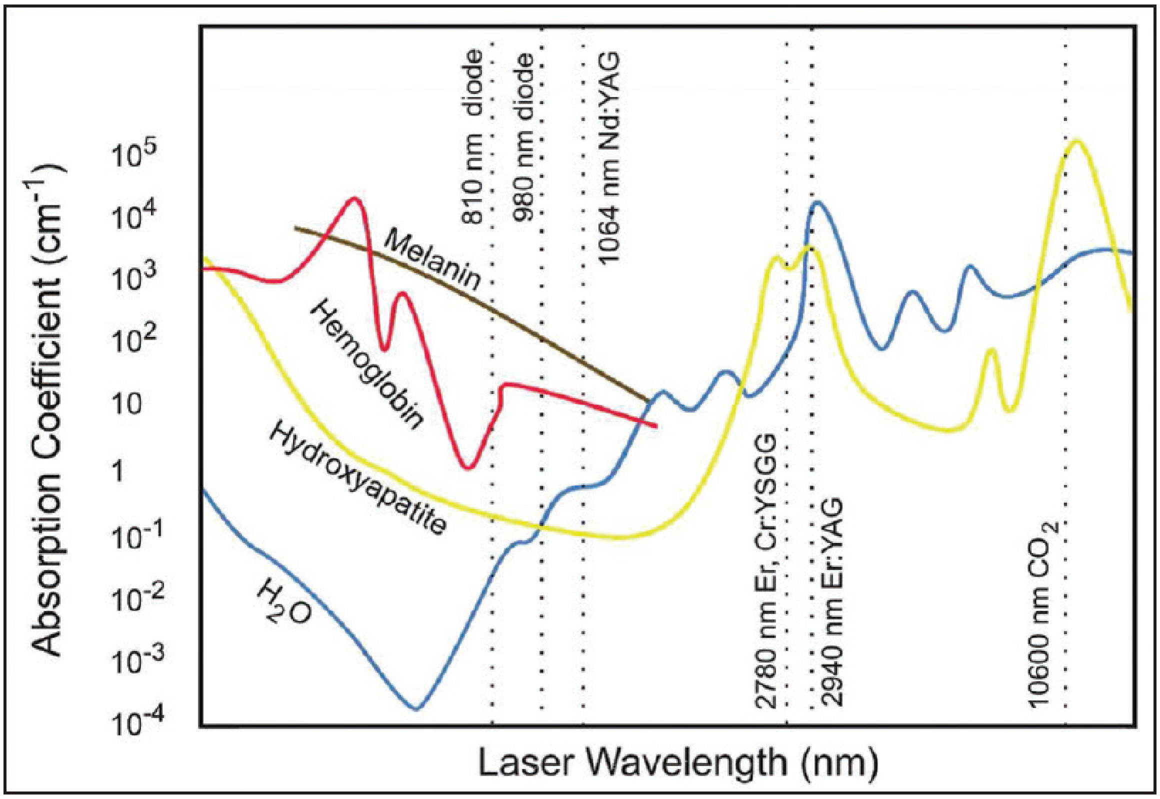

Figure 4. Characteristics of laser beam absorption as the function of wavelength for the main components of the tooth [26].

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3. Clinical applications and descriptions

3.1. Laser treatment of hard tooth substance (enamel and dentin)

The carious material contains a higher content of water compared with other surrounding dental healthy hard tissues. As a result, the ablation efficiency of caries is higher than other healthy tissues. There was a possible selectivity in removing carious material by using Er:YAG laser because of the various energy dose requirements to ablate the carious and also healthy tissue leaving those healthy tissues minimally affected. It was found that the Er:YAG laser can ablate the carious dentin effectively with the minimal thermal damage to the other surrounding intact dentins [19, 31, 32] (**Figures 5–8**).

The laser can remove infected and softened carious dentin to the same degree as the bur treatment [33]. However, the lower degree of vibration was remarked with the Er:YAG laser treatment (see **Figures 10–14**).

Figure 5. Decay present on the facial of the maxillary left lateral incisor.

Figure 6. The erbium laser used to remove the decay. No anesthesia was required.

Figure 7. After caries removal and preparation is complete.

Figure 8. Definitive direct-bonded restoration after preparation with the erbium laser [33].

The YSGG laser was cleared for classes I, II, III, IV, and V cavity preps, as well as caries removal, in 1999, with a similar clearance for children soon thereafter (1999). Since then, published reports have demonstrated the laser's ability to reduce and even eliminate the smear layer associated with traditional rotary instruments which can improve surface adhesion and bond strength for restorations [18, 20].

Also, because the laser reacts at a cellular level and helps to prohibit the pain response, most hard-tissue procedures can be completed without the aid of injected anesthetic [10].

The YSGG laser provides the precise treatment of pits and fissures on the occlusal surfaces of the molars as shown in **Figures 9** and **10**, which has aided in the growing discipline of "micro" and "minimally invasive" dentistry.

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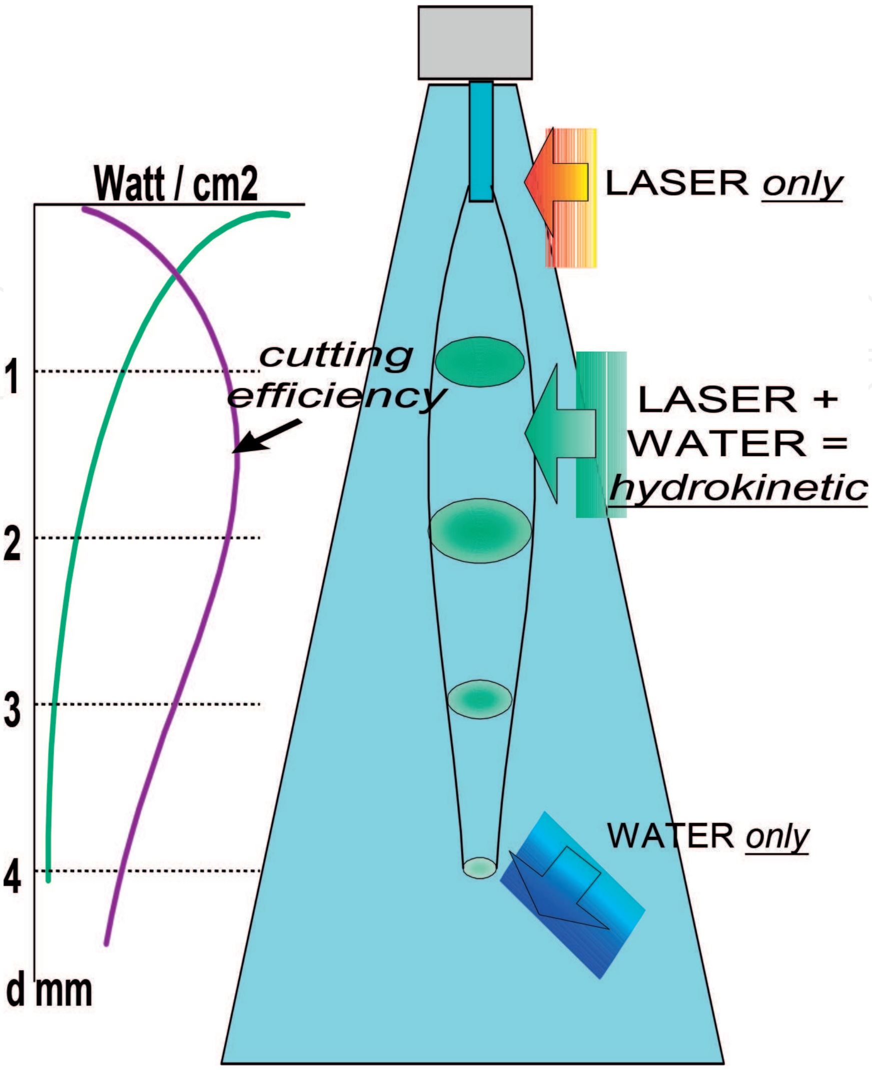

Figure 9. Cutting with YSGG (Waterlase). Optimization of the cutting efficiency: distance to tissue should be maintained at 1–2 mm (when power and spray are at proper settings).

3.2. Soft tissue

3.2.1. Periodontal disease

The YSGG laser was the exclusive laser evacuated for major indications in periodontal therapy, while other lasers such as the diode laser or Nd:YAG are absolved for soft tissue applications related to perio; none have been cleared for cutting oral osseous tissues, a core component of any periodontal program [34]. See **Figures 11–13**.

The YSGG laser was approved by the FDA for a wide array of indications related to the periodontal health like laser curettage, sulcular debridement, ostectomy, soft tissue flap elevation, removing of pathological tissues from bony sockets, and other related clinical applications [35].

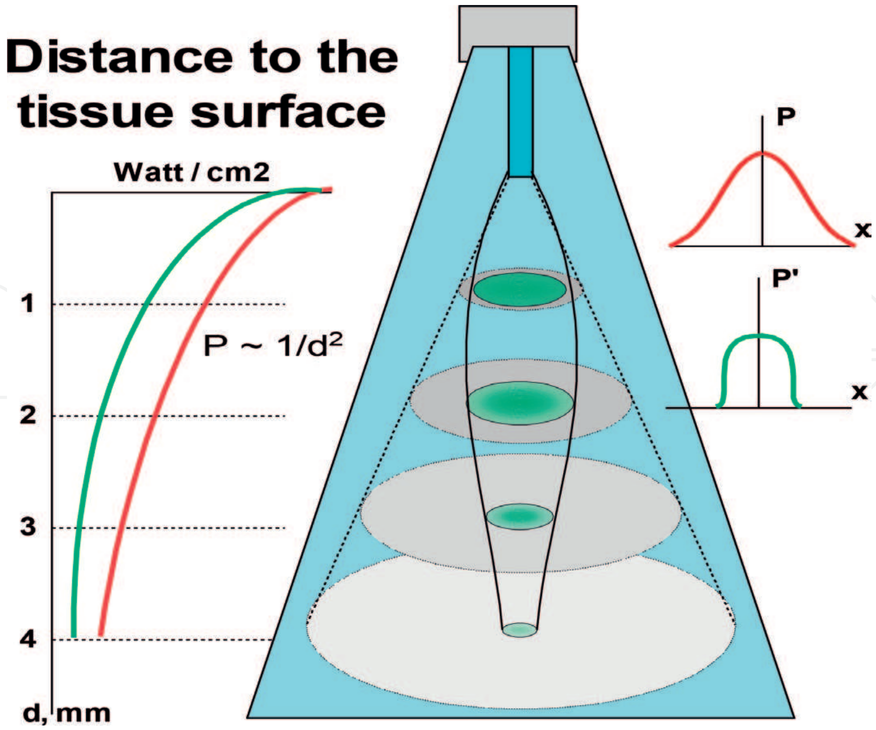

Figure 10. YSGG (Waterlase) parameters. Radiation wavelength and power (energy) density. To reduce cutting speed with Waterlase—“defocus,” back off from tissue; there is optimal distance range to cut tissue.

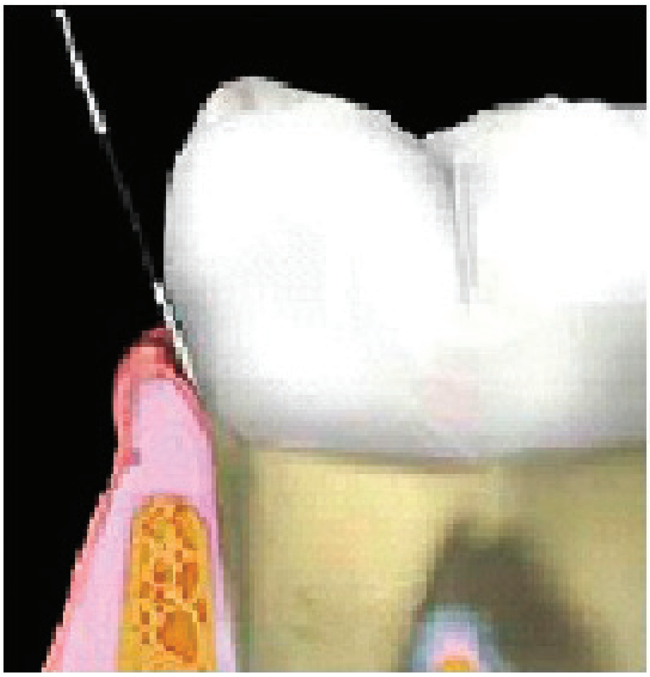

Figure 11. Hand scaling [35].

3.2.2. Removal of oral pyogenic granuloma

A variety of benign soft tissue swellings can be found arising from oral mucosa, most of which are inflammatory hyperplasia and granuloma. These lesions can be divided into those which

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Figure 12. Laser-assisted scaling using the Er,Cr:YSGG laser [35].

Figure 13. Thoroughly debrided root surface [35].

arise from the mucosa covering the alveolar processes and those which arise elsewhere in the oral cavity [36]. The soft tissue masses which are excised should be sent for histological examination.

Figure 14. Pyogenic granuloma of the left side of palatal mucosa [8].

Figure 15. Complete excision of granuloma by diode laser 5 W pulsed mode [8].

Figure 16. Pyogenic granuloma of the right side of maxillary alveolar mucosa [8].

A study by Mahmood et al. [8] has enrolled 35 patients with oral pyogenic granuloma. The type of laser, which was used in this study, is a diode laser with 810 nm wavelength, gallium aluminum arsenide (GaAlAs), output power of 15 W, and pulse duration between

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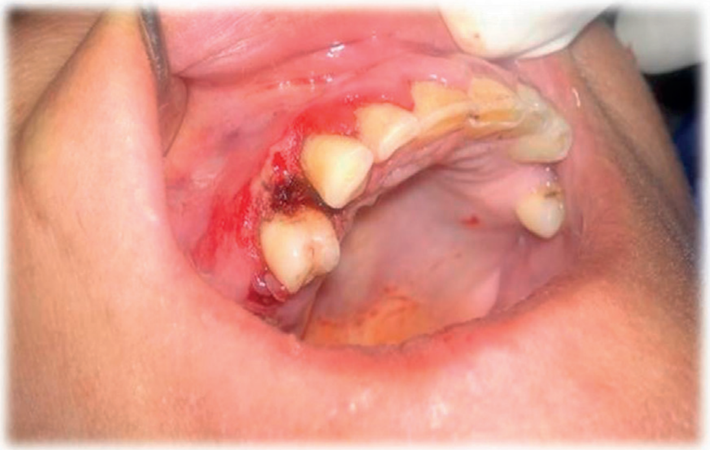

Figure 17. Complete excision of granuloma by diode laser 5 W pulsed mode [8].

0.1 and 1.0 second and works in continuous, single, and repeated pulsed modes. The laser surgical operations had been done at repetitive pulsed mode for 5–8 W maximum power, 0.2–0.4 seconds pulse duration, and 0.2–0.4 seconds pulse interval. The results were evaluated clinically depending on swelling, infection, disturbance of function, pain, and bleeding. The postoperative swelling was minimal to moderate. No sutures were required. No bleeding was seen neither intraoperative nor postoperative period. Postoperative pain was mild in few patients. No disturbance of function was observed [8] (**Figures 14–17**).

4. Conclusion

Using the laser dramatically can reduce the need of applying a high-speed drill to the tooth surface for any reason. Nevertheless, it was not yet to completely replace the drill because a laser cannot effectively cut reflective surfaces such as the metal and the porcelain.

The fact that a single instrument can remove the bulk amounts of enamel, dentin, and decay and then cut the soft tissue around the area typically requires an anesthetic to take the effect. It observes an exciting new era of effective laser dentistry.

The YSGG laser has practical viable applications across a wide clinical spectrum like hard tissue, soft tissue, bone, endo, and perio, and because it has utility in both hard and soft tissue applications, the Er,Cr:YSGG laser outperforms other conventional modalities in many ways.

Conflict of interest

The author declares no conflict of interest, financial or otherwise.

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