

# LASER APPLICATIONS IN CONSERVATIVE DENTISTRY

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## REZUMAT

Echipamentul laser reprezintă cu siguranță una din cele mai captivante tehnologii din practica medicinei dentare. Pe parcursul ultimelor două decenii, în literatură au apărut numeroase publicații științifice referitoare la echipamentele laser și aplicațiile lor în domeniul medicinei dentare. Actual, în funcție de lungimea de undă, echipamentele laser sunt disponibile pe o arie largă. Materialul face o trecere în revistă a celor mai comune, curente și nou apărute aplicații ale laserului în medicina dentară. Sunt prezentate indicațiile terapiei laser atât la nivelul țesuturilor moi cât și a celor dure. Deși laserul nu poate înlocui în totalitate toate tehnicile convenționale ale medicinei dentare, progresul este evident, în acest sens așteptându-se ca în viitor să devină o componentă esențială în medicina dentară conservatoare.

**Cuvinte cheie:** echipament laser, medicină dentară conservatoare, aplicații pe țesuturi moi/dure.

## ABSTRACT

Laser equipment represents surely one of the most captivating technologies in the practice of dental medicine. Throughout the last two decades, numerous scientific publications have emerged in literature, concerning laser equipments and their applications in the field of dental medicine. Presently, in accordance with their specific wavelength, laser equipments are available on a large scale. The material reviews the most common, most current newly-emerged applications of laser in dental medicine. The indications of laser therapy are presented - on soft as well as hard tissues. Although laser cannot fully replace all the conventional techniques of dental medicine, the progress is obvious, and laser is expected to become an essential component of conservatory dental medicine.

**Key words:** laser equipment, conservatory dental medicine, soft/hard tissue applications.

## INTRODUCTION

The emergence of laser system occupies a special place in the history of scientific innovations, the first operational laser systems being developed early in the 60's.

Laser was proposed as a mechanism by the American physicians Hard Townes and Arthur L. Schawlow, in 1953. Their achievement was a "Maser Optic", a device that, for the first time, could emit visible light, and not microwaves. Based on this idea, the first laser was completed, the consequent development being based on the use of knowledge from the field of microwaves (in 1960, the physicist

Theodor Maiman fabricated the first laser device, using a synthetic ruby.<sup>1,2</sup> The red light emitted by that prototype was 107 times stronger than the solar light. The radiation possessed only a single wavelength and propagated almost parallel, along a certain axis. In 1961, W.R. Bennet and D.R. Herriott have elaborated the first laser with helium-neon; one year later, the laser with semi-conductors appeared; and Ion Agârbiceanu completed the first Romanian atomic laser, with He-Ne. In 1964, C.K.N Patel produced the first laser with CO<sub>2</sub>, 1968 being the year in which, in Romania, the first laser with CO<sub>2</sub> and Nd was completed.<sup>3</sup>

Furthermore, the new acquisitions in various fields (physics, study of materials, chemistry, etc.), as well as the overall progress of technology, allowed a permanent development of the laser system. As the parameters of laser radiation became more and more varied, the domain of use became more extended, in the civil area as well as in the military one. The wide use of laser in medicine begins with the 8<sup>th</sup> decade of this century. The advantages that have imposed it are: matter processing without contact, high working

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speed, and outstanding precision. The first uses of laser in medicine were in the field of biology, the most important applications in this field referring to the fundamental research.

Low-energy lasers are used in biology, allowing high-finesse studies in spectroscopy, measuring the speed of movement of bacteria (hence, obtaining very fast antibiograms), determining the vitality and speed of movement of spermatozoa.

The use of laser in medicine presents a special interest, due to the spectacular progresses recorded in the treatment of various conditions. With no intention to cover all the fields of use of laser technology, we will enumerate a few more common: ophthalmology, E.N.T., gastroenterology, obstetrics-gynecology, dermatology, general surgery, plastic surgery, neurosurgery, cardiovascular surgery, pediatrics, urology, orthopedics, oncology, rheumatology, dentistry, etc.

In dentistry, laser has proved its utility on the soft oro-facial tissues, as well as on the hard, dental and osseous structures. Stern and Sognaes in 1964 began looking at the possible uses of the ruby laser in dentistry.<sup>4</sup> They were the first in a long list of investigators looking for a better way to treat dental patients with lasers. They began their laser studies on hard dental tissues by investigating the possible use of a ruby laser to reduce the subsurface demineralization. Stern and Sognaes found a reduction in permeability of the exposed enamel to acid demineralization. A number of other researchers looked at the effect lasers had on dental hard tissues.<sup>5-10</sup>

Since these preliminary studies, numerous reports have been directed to both soft and hard dental tissue use. The penetration of lasers in dentistry has known a spectacular evolution, in comparison with other areas of medicine, in which, a decade earlier, laser was already a consecrated instrument.

There are numerous potential applications of lasers in dentistry. Following is a presentation of possible uses of lasers on soft and hard tissues.

## **SOFT TISSUE APPLICATIONS**

One of the early reports in 1968 of lasers in oral and maxillofacial surgery was by Goldman et al.<sup>11</sup> They reported on the use of the CO<sub>2</sub> laser in preliminary investigative surgery. There was some concern of these early investigators about possible damage to the underlying bone around teeth. Clayman et al.<sup>12</sup> looked at the defects caused by the CO<sub>2</sub> laser to evaluate the effect of this laser on bone in both the short and long term. They reported in 1978 that the CO<sub>2</sub> laser does,

in fact, cause minimal damage to the bone under the gingiva being treated, but the gingiva healed well, albeit over a longer period of time.<sup>12</sup> A pioneer in the area of clinical periodontal and oral surgery is Pick, who, along with colleagues in 1985 reported on the laser gingivectomy.<sup>13</sup> This procedure is usually limited to those lesions caused by drug-induced gingival overgrowth. Some drugs like *phenytoin sodium*, *cyclosporine*, *nifedipin*, and *diltiazem hydrochloride* have been implicated most often and have been reported to cause gingival overgrowth.

Pick discussed the technique for removal of overgrown gingival tissue, paying close attention to and protecting the teeth and the surrounding bone. The advantages of using the CO<sub>2</sub> laser for this type of surgical procedure included dry and bloodless surgery, instant sterilization of the surgical site, and reduced bacteremia.<sup>14</sup> Furthermore, mechanical trauma was reduced, and postoperative swelling and scarring, and postoperative pain were minimal. Some of the disadvantages included the cost of the laser for the dental practitioner, loss of the tactile feedback since the CO<sub>2</sub> laser is used in the noncontact mode, and the special training needed for both the surgeon and assistant. Pick and Pecaro,<sup>15</sup> Abt et al,<sup>16</sup> and Frame<sup>17</sup> have all reported the successful use of the CO<sub>2</sub> laser in the treatment of oral pathologies.

The soft tissue applications have been restricted mostly to incising and excising masses from the mucosa and gingiva in the oral cavity. Only recently have reports suggested that the CO<sub>2</sub> laser may have a unique ability in periodontal surgery to impede the postoperative growth of oral epithelium. A major problem that occurs after surgery around teeth is that the epithelium grows faster than the healing connective tissues. The swiftly growing epithelium will progress down along the root surface of the tooth, causing a deep pocket to form next to the tooth. This pocket is a site for accumulation of bacteria and debris. The bacteria and debris are not cleansable in these deep pockets and can lead to a poor prognosis after periodontal surgery. Rossmann and Israel<sup>18,19</sup> have reported on a technique where the CO<sub>2</sub> laser was used to remove the epithelium from the connective tissue around the tooth. They have shown inhibition of epithelial growth around the tooth.<sup>18,19</sup> More research needs to be performed in this area, but it seems as if the CO<sub>2</sub> laser may have the unique characteristic of being able to remove a thin layer of epithelium cleanly, unlike anything now available in dentistry.

Lasers can be beneficial for selective removal of malignant tissue with the aid of porphorin compounds. These compounds are selectively

absorbed by malignant cells and when combined with specific wavelength laser light, malignant tissue is destroyed. Some of the bacteria involved in periodontal disease have porphorin compounds in their cell walls. Lasers may be used selectively to kill these bacteria, leaving other nonpathogenic bacteria intact. This action may also be expedited by using compounds similar to the porphorins that are painted in the gingival before laser treatment.

To date, soft tissue applications have constituted the primary area for the clinical use of lasers in dentistry. Clinicians and patients alike have great interest in the development of lasers for dental use. In order to expand future applications in dentistry, developments must be based on understanding the effects of various wavelengths and other parameters on laser/tissue interactions in the oral cavity. With this understanding, lasers can be developed to treat specific conditions or for specific purposes in the mouth.

## HARD TISSUES APPLICATIONS

One of the most obvious applications of lasers is for the controlled removal of dental enamel, dentin, bone, or cementum. Using lasers to ablate hard dental tissue for bonding pretreatment, dental decay removal, and tooth preparation has received considerable attention by researchers. This worthy goal can be achieved only after more information is available on tissue/laser interactions and technology can be developed to make use of this knowledge. Replacement of the dental drill is a real possibility for the future.

**Cavity preparation.** In the hope of improving the dental treatment, numerous researches were performed in the last decades concerning the use of "optical dental bur" to prepare the hard dental substance.<sup>20-30</sup> At the beginning, the effect of ruby laser radiation on the enamel was studied (already performed a few years earlier by Goldman, Stern and Sognnaes, 1964);<sup>31</sup> and, as the devices became available, the first results were reported in regard to the use of CO<sub>2</sub> laser (Lobene et al, 1968),<sup>32</sup> Nd:YAG laser (Yamamoto and Ooya, 1974),<sup>33</sup> and Argon laser (Goodman and Kaufmann, 1977). Until today, several hundreds of publications have emerged on the use of lasers in dentistry.

Besides removal of hard dental tissue, decayed and healthy, there are in study means for processing the surface of the enamel (resistance increase, sealing, achieving retentive models for the adherence of composites), and of dentin (sterilization, obliteration of dentinal tubules).<sup>34-40</sup> However, as a limiting factor

in removing the enamel and the dentin by means of laser radiation, for most types of lasers the thermal side effect has occurred. In case of lasers that operate in continuous mode, it is the principal mechanism of the interaction between laser and hard dental tissues (thermal mechanism), and in the case of pulsed lasers it is a consequence of the secondary mechanism of interaction, the principal mechanism being the acoustic one. This fact determined Stern (1974) to conclude that, if new ways of radiation production will not appear, laser will remain with very strict limitations concerning its employment in dentistry. The prognosis of Stern remains valid for more than a decade, until other lasers with a more favorable wavelength and an optimal operative frequency will lead to encouraging results. A possible removal of the dental hard tissue, with no thermal side effects, was possible once the superpulsed CO<sub>2</sub> lasers were introduced.<sup>41-43</sup> One of the most efficient CO<sub>2</sub> lasers, utilized with the purpose of dental hard tissue ablation, is the one with transversal stimulation or CO<sub>2</sub> TEA (the Alexandrit Laser with double frequency). The threshold for removal reduces visibly, for dentin and demineralized carious enamel, which has led to the conclusion of using this laser for selective removal of caries. With the purpose of reducing the secondary thermal effects, cooling with water is indicated, with no losses in the intensity of laser beam.<sup>44</sup> At the same time, a removal of hot debris also occurs, with cleaning and cooling the impact zone, which will lead to a minimization of plasma emission. However, it has to be mentioned that the presence of plasma may also diminish the laser effect by absorption of laser radiation, before it reaches the lever of the tooth, having as a result the reduction of the ablation efficiency.

Since 1987, the clinical perspective of laser use on hard dental tissues has grown by introducing the Er:YAG, Er,Cr:YSGG lasers,<sup>45-58</sup> which have the advantage of reducing thermal effects, and of creating a precise contour of the section zone.

In the meantime, the researches were focused on the Nd:YAG, Excimer, Holmium, Argon and diode laser use.

As a general therapeutic guidance, before introducing a new therapeutic method, nay a new technology, the clinical studies represent the basic premise. Only after a differential analysis and the design of a strictly defined therapeutic plan, utilization of a new technology, such as the laser technology, may be promising and advantageous. Most doctors know the term "laser", but, often, the specific properties of the radiation are misunderstood, which generally leads to therapeutic mistakes. This is the explanation for the

necessity of so many experiments and fundamental and clinical researches, for clarifying the problems connected to the utilization of laser in dentistry, improvement and completion of traditional methods, and, throughout the technological evolution, even their total replacement.

One question discussed continuously in exploring laser uses is the speed of preparation. The thermomechanical, microexplosion-like ablation utilizes the laser energy very efficiently. Much less energy is needed compared to vaporization. The speed of tissue removal increases roughly linearly with the average power of laser radiation. With moderate pulse energies and the repetition rates used in clinical studies, tissue-removal speed in sound enamel is clearly slower than that obtained with a high-speed turbine. In dentin, a tissue-removal speed comparable to low rotating burs can be achieved. If tissue is softened by canes, the laser ablation rate increases. Thus, the laser is competitive in caries removal, but for large preparations requiring the removal of relatively large amounts of sound enamel, the high-speed turbine is more convenient in terms of preparation time.

The rough tooth surfaces produced by laser ablation are considered to provide a good retention of composite or compomere filling materials. A variety of studies on bond strength and marginal seal have been published, especially during the last few years.<sup>50,59</sup> Methods and results are both very different. The main variables are represented by: the parameters of the laser, the material used for the filling, and the combination with acid etching or not. One essential point for good bonding and good marginal seal is the quality of the surfaces. The enamel remaining after Erbium laser cavity preparation with high power is usually covered by tiny flakes. When these are strained, they can break in succession, leading to reduced bond strength. The literature indicates that rougher cavity walls can also be filled, but in this case additional acid etching seems advisable. Using thin optical fibers, fissures can also be precisely conditioned without acid before sealing. Dentin surfaces are less rough after ablation and thus less problematic in this sense. Here, high bond and shear strengths can be achieved with simple defocused irradiation. For conditioning, less time is needed using the laser than when etching conventionally. Furthermore, drying the surface with the laser is very quick, efficient, and gentle.

Although exhibiting only small overall thermal side effects during ablation, the Erbium laser has been demonstrated to possess bactericidal abilities.<sup>60</sup> The reason is that high surface temperatures can be achieved for a short time by subablative irradiation.

In this case, complete pulse energy is transformed to heat within a thin surface layer corresponding to the optical penetration depth. As calculations and measurements show, these high temperatures are limited to the surface and to a short time interval following irradiation. Irradiation of caries by a sequence of laser pulses leads to consecutive desiccation and sterilization. No accumulation of heat by rapid repetition of laser pulses is necessary to achieve sterilization. Even with long time intervals in between, multiple pulses are potent. The Er:YAG laser can be used to disinfect cavity preparations in case of residual bacteria contaminating, otherwise intact enamel or dentin, or in fissures prior to sealing.

In addition to the morphological qualities, an important role in the practical use of a laser as preparation instrument is held by the efficiency of ablation and rate of erosion. In the case of an laser with Excimer, the depth of the crater, per impulse, is limited to fractions of millimeters (193  $\mu\text{m}$ , Frentzen et al, 1989), and a few millimeters, respectively (308 nm, Liesenhoff et al, 1989). A low efficiency of removal, for the enamel as well as for the dentin, was determined for a laser with Alexandrite, with frequency doubling ( $\lambda = 377 \text{ nm}$ ;  $\tau = 200 \text{ ms}$ ). The removal threshold decreases visibly for dentin and decayed, de-mineralized enamel (Henning et al, 1991; Rechmann, 1993). Pasen et al have presented a cavity achieved in dentin with an Nd:YAG laser with free functioning. From 1987, the majority of researches were focused on the use of Er:YAG, Er,Cr:YSGG and diode laser.

Ablation of carious dentine and enamel by a dye-enhanced low-power CW diode laser has been shown to be feasible and it could be developed into a practical method for cavity preparation. The technique offers selective and efficient ablation of carious dentine and enamel. Thermal side effects due to the temperature increase in the pulp can be controlled by the laser power and dye concentration used. In fact, the researches indicate that, in a clinical situation, the temperature rise in the pulp should be negligible. For improved clinical versatility, a suitable laser tool can be implemented in an inexpensive package using fiber delivery of the diode light. The clinical relevance of dye-assisted laser ablation has been demonstrated, providing incentives to pursue this approach further.

**Dentin hypersensitivity.** There are numerous studies in the medical literature regarding the use of laser therapy in dentin hypersensitivity treatment. The best results have been obtained when the affected areas were exposed to  $\text{CO}_2$ , Nd:YAG, Er:YAG and diode laser irradiation. Colojoară et al<sup>34</sup> showed that the

dentin sensitivity can be reduced without any damages to pulp vitality, by using the CO<sub>2</sub> laser.

There are well-known aspects related to the use of low-level laser therapy in dentin hypersensitivity. Previous researches have shown that the diode lasers were tested for this matter. Lizarellia used as an efficient dose to reduce dentine hypersensitivity the 630nm diode laser, 2J/cm<sup>2</sup> per point (three points). Schwarz<sup>61</sup> used Er:YAG laser (80mJ / pulse, 3Hz) concluding that it was effective in desensitizing the hypersensitive dentine. Colojoară et al<sup>34</sup> have shown that, when using the CO<sub>2</sub> laser (18.75mJ, 3W 5 pulses of 50 ms), in parallel direction with dentine tubules, the desensitizing effect was obvious after three exposures.

## DENTAL MATERIAL CURING

Another use of light in dentistry began with the advent of photopolymerized dental composite materials. The first materials introduced in the late 1970s were cured with a light in the ultraviolet wavelengths.<sup>62,63</sup> Due to the concern about Uv light in the mouth, composites that polymerize in the visible light spectrum were developed.<sup>64-66</sup> These composites were used for anterior esthetic dental restorations and also for sealing the occlusal pits and fissures in posterior teeth to reduce decay. Powell et al showed that an argon laser requires shorter curing times and that the materials-dentin bond strength were considerably stronger when cured with the laser.

Kelsey et al.<sup>67-68</sup> reported that the argon laser also decreased curing time and further stated that all physical properties were enhanced when compared with conventional light curing units. The variables that control the depth and extent of cure include time of exposure, composite material, wavelength and intensity of the light, and particle size of the filler. Because laser light is intense, monochromatic, coherent, and collimated, it was thought that it may be a superior light source for photopolymerization of dental composite materials. Blankenau<sup>69</sup> showed that if the testing time after laser polymerization varied, there were considerable differences in results taken during the first 20 days postpolymerization.

Wigdor<sup>70</sup> looked at the cure depth of composite materials using two lasers (HeCd  $\lambda=443$  nm and Argon  $\lambda=488$ nm). Using a 50 mW laser, the amount of cure depth was about the same with the laser as the conventional xenon light source presently used by dentists for composite curing filtered to 460 nm. From the results reported, the argon and HeCd lasers appear to be similar to present methods of curing dental composite resins. The use of a more powerful laser

may have cured the material faster and deeper. Since the physical properties of the composites post-laser irradiation were not determined, no judgement can be made regarding improved results with the laser.

Current researches<sup>71</sup> reported that, used at powers of 250  $\pm$ 50 mW for 10 s per increment, the argon laser provides good curing of light-activated restorative materials in a shorter period of time with equal or better physical properties than the conventional halogen curing light.

## ENDODONTICS

In endodontics, lasers have been used as adjuvant treatment in both low-intensity laser therapy and high-intensity laser treatment to optimize the outcome of clinical procedures.<sup>72-77</sup> Low-intensity laser therapy induces analgesic, anti-inflammatory and biomodulation effects at a cellular or molecular level, with photochemical responses improving tissue healing processes and less postoperative discomfort for patients. The clinical application of low-intensity laser in endodontic therapy has been considered useful in: postpulpotomy (with the laser beam applied directly to the remaining pulp and on the mucosa toward the root canal pulp); postpulpectomy (with the irradiation of the apical region); periapical surgery (irradiating the mucosa of the area corresponding to the apical lesion and the sutures).

It must be taken into account that intracanal laser application requires a laser beam delivery system through a fiber with an appropriate diameter for efficient apical irradiation.

The effect of laser intracanal radiation depends on the type of laser used and on the output of the laser.<sup>78</sup> One of the main concerns is the laser's effect of thermal conduction of heat and transmission of energy through dental hard tissue to the external root surface. In the same manner, energy parameters of laser intracanal radiation must not cause more than a 10°C temperature rise on the external root surface to avoid thermal damage of surrounding tissues. For the same reason, laser irradiation of hard dental tissue should be done in pulsed mode with short pulse widths, making it possible to operate at high powers with relatively long rest periods.

The clinical indications for high-intensity laser radiation in endodontic treatment are:

**Bacterial reduction.** Intracanal radiation absorbed by tissue substances produce a thermal effect capable of eliminating microorganisms. However, it is important to establish methods to minimize and control the undesirable effects attributed to the thermal

interactions with tissues. The extent of the thermal damage may be controlled by adjusting laser operating parameters, such as spot size, power density, exposure time, repetition rate, and the pulse duration.

High-intensity lasers such as Nd:YAG (neodymium: yttrium, aluminum, garnet), Ho: YAG (holmium: yttrium, aluminum, garnet), Er:YAG (erbium: yttrium, aluminum, garnet), Excimer, CO<sub>2</sub> (carbon dioxide) and diode have been recommended successfully as an adjuvant method in the endodontic treatment of contaminated canals to remove bacteria from the root dentinal surface as well as from deep dentinal layers.<sup>79-80</sup>

It is assumed that bacteria are critical for the development and maintenance of apical periodontitis, and that the efficacy of endodontic rinse solutions and medication against bacteria in vivo is limited; infections can be resistant to routine endodontic treatment, jeopardizing the success of the therapy. Persistent infection in contaminated canals is frequently attributed to the typical root canal flora (predominantly anaerobic) and its products invading the dentinal tubules and accessory canals. Another cause may be the presence of extraradicular infection due to a bacterial biofilm on the external apical root surface. In addition, teeth with large lesions usually harbor more bacterial species, have a higher density of bacteria in their root canals when compared with small lesions, and consequently, heavier bacterial penetration occurs within deep dentin, infecting more dentinal tubules.

The ability to eliminate bacteria even in deep dentinal layers increases the success rate of endodontic therapy of contaminated canals, avoiding periapical surgery. Compared with the results achieved with the conventional bactericidal technique, the high power diode laser seems to be highly suitable for killing bacteria in infected root canals.<sup>81</sup>

**Dentinal root canal treatment.** Depending on the interaction between the wavelength emission and the target tissue, high-intensity lasers are capable of performing morphological superficial changes on root dentin, influencing the permeability of the walls and the adaptability of the root filling to the root dentin. The thermal effect of the same wavelength (depending on tissue interaction) may cause melting and recrystallization of dentinal structure, or, on the other hand, may expose dentinal tubules.

An in vitro study with intracanal Nd:YAG laser radiation before obturation showed less leakage between root filling materials and dentinal root walls when compared to canals not treated with the laser. Another study showed less leakage with intracanal Nd:YAG laser use compared to both the control

group without laser treatment and the group treated with Er:YAG laser.<sup>82-84</sup>

**Intracanal soft tissue vaporization.** The potential of specific wavelengths to vaporize soft tissue allows the removal of intracanalicular granulation tissue present in internal root resorption cases. In addition, disinfection will be achieved in contaminated root-resorbed canals due to the bactericidal effect of thermal interaction.<sup>78</sup>

**Low-intensity laser therapy.** High-intensity laser radiation reaching the target tissue in a defocused mode with low power works like low-intensity laser therapy, and its analgesic, anti-inflammatory, and biomodulation effects have also been considered useful in the wound healing process. Therefore, such high-intensity lasers could also be useful following root canal treatment, pulpotomies,<sup>85</sup> and pulpectomies, as well as after surgical procedures like apicectomy.

**Endodontic surgery.** The advantages of laser application in endodontic surgery are identical to those that have been reported for other oral surgical procedures. In addition, the use of lasers to replace aerosol-producing handpieces in periapical surgery can reduce the risk of contamination of the surgical environment by blood borne pathogens. The unique properties of laser light as they pertain to endodontic surgery are listed as follows: *precision; coagulation; decreased postoperative pain, edema and reduced scarring; sterilization; selective absorption.*<sup>78</sup>

## PERIODONTICS

In *gingivectomy* and *gingivoplasty*, various lasers can be used which have different wavelengths, corresponding absorption characteristics, different modes of action, and as a result, different indications.<sup>2, 86-90</sup>

The laser routinely used for removing gingival hyperplasia is the CO<sub>2</sub> laser.<sup>105</sup> It is characterized by a good hemostasis, a favorable course of healing, little postoperative pain, and a low tendency to scarring and swelling. In contrast to conventional methods, the occurrence of bacteremia is fairly unlikely. This is why this laser is particularly suitable for gingivectomy and gingivoplasty in patients with immune deficiencies or who are undergoing immunosuppression, e.g., patients receiving medication after organ transplants.

The use of a Nd: YAG laser in the treatment of hyperplastic gingiva by gingivectomy has a number of advantages compared to conventional gingivectomy. Bleeding and tissue traumatization are reduced. Wound healing is accelerated by the sterilization of the operating field, and swelling, wound

contraction, and postoperative pain occur only to a limited extent.<sup>91,92</sup> Therefore, in periodontal surgery, Nd:YAG laser can be used for the following interventions:<sup>93</sup>

- Phrenectomies, bridectomies;
- Gingivectomies in hypertrophies and tumoral lesions;
- Gingivoplasties with physiognomic or hygienic purpose;
- Scaling and planning of root surfaces (in combination with the use of curettes);
- Minor adjustments of the healing area, in the first stage of implant introduction;
- Revealing of the implant, in the second stage;
- Gingival retraction, with the purpose of prosthetic impression.

In these types of interventions, with the use of laser, the sensation of pain is reduced and the infection risk diminishes. In comparison with other electro-surgical methods, laser does not heat the surrounding tissues and does not determine muscular contractions, thus decreasing the postoperative risk for bleeding, tumefaction and pain. An optical fiber with a diameter of 320  $\mu$ m is used, in contact position. The laser power is of 1.75-3 W/impulse, with 20-30 impulses/second. In most cases, anesthesia is not necessary, the occurrence of a minimal amount of pain varying from one patient to another. Clinical studies have shown that the application of typical anesthesia can diminish the laser energy, thus decreasing its capacity to section. As a consequence, the energy administered should be greater. Initially, vaporization of the tissue is achieved using 20 impulses/s, 1.75 W/impulse. The tip of the fiber must not exceed the probe with more than 2-3 mm, in order to maintain the control and the precision of the intervention. The fiber tip is applied in slight contact with the affected gingival area, with no pressure. The tissues will be vaporized one layer after another, with back and forth movements, with a rapid, decisive and regular movement. For fibrous tissues, energies of 2.25-3 W and 20 imp/s are used. In order to avoid the occurrence of pain sensation, a water cooling system is used, situated 2-3 mm from the area, maintaining the laser on.

For phrenectomies, the same dimension of fiber is used, at identical power, in contact, and a local anesthesia can be performed in this situation. The fiber will be held vertically and not perpendicularly on the insertion of the phrenum. It will be moved along the entire surface, and the maneuver will be repeated until the entire tissue has been removed. The cooling will be done on a 7-8 mm area from the incision, in order to avoid dehydration of tissues and delaying of healing.

If anesthesia is employed, the amount of energy and the number of impulses needs to be greater.

In the treatment of soft tissues, there is a risk of accumulation of carbonized debris on the fiber extremity, which reduces its capacity to section. That is why regular cleaning of the fiber is necessary.

In the context of *subgingival curettage*, one of the major aims is to achieve the absence of germs or a reduction of the germ count in the subgingival region. Above all, the level of periodontopathogenic germs (marker germs: primarily *Actinobacillus actinomycetemcomitans*, *Porphyromonas gingivalis*, *Prevotella intermedia*) must be reduced below the critical mass. Based on experience with reducing germ levels by laser, it particularly lends itself as a supportive measure in periodontology.

In this context, good results are obtained with the Er:YAG laser,<sup>94</sup> the diode laser,<sup>93</sup> and the pulsed Nd:YAG laser.<sup>86</sup> However, other wavelengths can also be used.

Due to the optical fiber and the action spectrum, the Nd:YAG and diode lasers are prime candidates for use as adjuvant lasers in *closed curettage*. Several studies recommend a setting of 1.25 W to 3 W, in order to avoid the risk of irreversible damage resulting from the blind guidance of the beam in the gingival pockets.<sup>86</sup> Under these conditions, there are also reports of possible routine use of a pulsed Nd:YAG laser in pocket therapy without any disadvantages, as neither destructive effects on adjacent tissue or dental pulp nor gingival trauma have been demonstrated. Luomanen et al examined the proliferative activity of epithelial cells and fibroblasts in laser wounds and found that it was not reduced.

The following effects are found in pocket therapy with the Nd: YAG laser:<sup>78-86</sup>

- Vaporization of diseased tissue, with effective removal of ulcerated pocket epithelium;
- Reduction of the subgingival bacterial flora;
- Selective destruction of melanin-producing bacteria, eg. *Porphyromonas gingivalis* and *Prevotella intermedia*;
- Delayed recolonization and greater effectiveness in the reduction of the subgingival flora as compared to conventional mechanical therapy over an observation period of 28 days;
- Similar, if not even better, reduction of the pocket depth by laser therapy in comparison with mechanical treatment. A similar situation exists regarding plaque and bleeding indices;
- Compared to the results of mechanical therapy, there are no differences in loss of attachment, degree of recession, sulcus fluid rate, and degree of loosening.

Moritz et al<sup>95</sup> showed that the diode laser reveals a bactericidal effect and helps to reduce inflammation in the periodontal pockets in addition to scaling. The diode laser therapy, in combination with scaling, supports healing of the periodontal pockets through eliminating bacteria.

All three of the lasers listed for gingivectomy/gingivoplasty (Er:YAG, Nd:YAG, diode) can be used to assist in open curettage, although the procedure differs greatly. With the Nd:YAG and diode lasers, gingivoplasty or laser gingivectomy is already performed during initial treatment. After that, the periodontia to be treated are exposed for treatment by creating a modified Widman flap. The inflamed tissue on the inside of the flap is treated with the Nd:YAG or diode laser over the entire area and in constant contact. The entire surface of the bone and the root is likewise treated, but at lower power and in noncontact mode to improve germ reduction.

When using the CO<sub>2</sub> laser,<sup>87</sup> care must be taken to absolutely avoid contact with the enamel, root, and bone, surfaces, as good coupling of this laser to these materials can lead to carbonization and thus to retarded wound healing.

## **PREVENTIVE DENTISTRY**

The use of lasers in preventive dentistry implies the knowledge of the interaction between laser and dental tissues.<sup>2,33,96-98</sup> In this regard, there have been very early studies related to the investigation of the optical properties of dental tissues, in relation with the various wavelengths of lasers and with the duration of laser impulse. The first studies performed “in vitro” by Stern et al,<sup>4</sup> with a ruby laser ( $\lambda = 693.4$  nm), have demonstrated that laser can be used for heating the enamel surface, with a direct consequence the increase in the enamel resistance to demineralization. Vahl,<sup>99</sup> through his studies of E. M. and X-ray diffraction, has demonstrated the ultra-structural and crystallographic changes resulted after laser irradiation. Subsequently, the studies of Yamamoto et al<sup>33</sup> have shown the potential of the Nd:YAG laser ( $\lambda = 1.064$  mm) to fuse enamel prisms on high energetic levels ( $\sim 1$  GW/cm<sup>2</sup>) and thus to determine a high increase in its resistance to demineralization.

Most of the beginning studies were performed using lasers with wavelength in the infrared and visible specter, i.e., whose radiation is well absorbed by hard dental tissues.

Similar studies were performed using the carbon dioxide laser. The enamel, the dentin and the cementum contain hydroxiapatite as a main mineral

component, which presents a maximum of absorption in the region of infrared ranging from 9.0 to 11.0 mm. In consequence, CO<sub>2</sub> laser radiation (in IR) is absorbed more efficiently than that in the visible specter. Fowler,<sup>100</sup> Nelson and Featherstone,<sup>101</sup> Nelson and Williamson,<sup>102</sup> Meurman et al,<sup>103</sup> comparing the effects of the CO<sub>2</sub> laser with the Nd:YAG on synthetic hydroxiapatite, showed that only CO<sub>2</sub> laser has a clearly inhibiting effect. In the same area we can list the studies of Launay et al<sup>104</sup> who compared the effect of Nd:YAG (pulsed), Argon (continuous) and CO<sub>2</sub> (continuous) lasers. Nd:YAG laser (pulsed) (200 – 2,000 J/cm<sup>2</sup>) does not determine fusion in the enamel prisms, the radiation diffusing towards the pulp, where it determines its heating. The ionized Argon laser (300 – 10,000 J/cm<sup>2</sup>) determines irreproducible modifications, due to the presence of the surface organic component that determines the absorption of laser radiation. Continuous CO<sub>2</sub> laser (250 – 1,000 J/cm<sup>2</sup>) determines melting of the enamel surface, with a degree of pulp heating. Stern et al,<sup>105</sup> Lentz et al,<sup>106</sup> based on the experiments performed with the continuous CO<sub>2</sub> laser, have demonstrated the ultra-structural and phase changes on the enamel surface treated with this type of laser. Featherstone et al<sup>107</sup> and Nelson et al<sup>108</sup> have measured the effects produced by CO<sub>2</sub> laser irradiation (with a wavelength varying from 9.3 – 10.6  $\mu$ m) on enamel and dentine, using low energetic levels, in a pulsed mode. Their E. M. studies have demonstrated that the maximum effect of surface heating is more evident if wavelengths from 9.3 to 9.6  $\mu$ m, are used than for wavelengths of 10.6. All these studies proved that the only system for application in preventive dentistry would be the CO<sub>2</sub> laser, with a wavelength between 9.3, 9.6  $\mu$ m and 10.6  $\mu$ m.<sup>109-110</sup>

Researches performed using the continuous CO<sub>2</sub> laser with interaction time from 50 ms to 2 sec, showed that this time was too great in relation to the time of enamel relaxation. Because of this long interaction interval, a large part of the absorbed energy of laser is directed from outside the enamel surface towards the interior, determining on one hand an insufficient melting temperature for the enamel, and on the other hand involvement of the pulp through temperature increase within the pulp chamber. Of course, it would be ideal if the duration of the laser impulse was proportional with the duration of tissue thermal relaxation. If the duration of the impulse is too small, the density of laser power deposited could be too large and hence it would determine ablation of tissues, instead of heating and fusion of enamel prisms. Pulsed lasers offer the possibility to increase the power of the

peak density (PPD1) while maintaining the impulse energy density constant. This means that fusion, melting, and re-crystallizing of enamel crystals can be achieved on a very thin enamel surface, without involving the underlying tissues – the dentin and the pulp, respectively.

Meurman et al<sup>103</sup> and Nelson et al<sup>108</sup> have measured the effect of irradiating the enamel and dentin with low energy CO<sub>2</sub> pulsed laser (9.3-10.6 mm). Multiple impulses were used, with duration of impulse of 100 - 200 ms and an irradiation intensity of MW/cm<sup>2</sup>/impulse. The result was a melting of the surface of enamel and dentin, just like in the case of continuous CO<sub>2</sub> laser, but without in-depth propagation of the thermal effect. Recent studies of the same researchers have proved that, using the pulsed CO<sub>2</sub> laser with an impulse duration of 100 ms and with an optimal wavelength of 9.3 to 9.6 mm, a significant irradiation intensity can be obtained (< 25 kW/cm<sup>2</sup>), each impulse being used with maximal efficiency.

Research has shown that pretreatment of dental enamel with carbon dioxide laser light within certain parameters can markedly reduce subsequent acid dissolution of the enamel. Since dental decay is a demineralization process, such laser treatment is expected to be useful for inhibition of tooth decay. Understanding the effects of the parameters involved will allow for optimal conditions to be chosen for clinical inhibition of caries progression. The potential is good for this concept to be expanded for: *treatment of early enamel lesion to inhibit progression; treatment of occlusal surfaces; prevention of root caries insusceptible sites; treatment of early root caries to inhibit progression.*

## **ORTHODONTICS**

The applications of various types of lasers in orthodontics depend on the type of treatment desired, as well as on the potential advantage of laser techniques over conventional methods.<sup>2</sup> The main applications of lasers in orthodontics are laser scanning, holography, and applications on soft and hard tissues.<sup>109</sup>

Classical methods of acid etching imply use of phosphoric acid (37%), as a gel or solution, on the enamel surface. The time of action is of 15-60 s. The enamel appears mat, after washing and drying.

The use of lasers as an alternative for enamel conditioning has determined solving other problems as well, such as:

- Should the acid cover all the labial surface, or only a small portion, outside the base of the bracket?

- What is the optimal time for acid etching?
- Should the time be prolonged when teeth previously underwent fluoridization procedures?
- Is acid etching allowed for teeth which present signs of total demineralization?
- How much enamel is affected by acid etching, and how deep are the histological alterations? Are these reversible or irreversible?

The most tested, for *enamel conditioning*, are CO<sub>2</sub> laser, Nd:YAG laser, Er:YAG laser, Excimer laser, etc. Present techniques subscribe to the tendency to find a “proper” laser in order to obtain a resistant and long-lasting conditioning. Clinical studies have demonstrated clearly that pulsed CO<sub>2</sub> laser etching techniques determine a very good conditioning of the human enamel (98.9%), in view of composite laminating, in comparison with the one achieved with phosphoric acid (98.5%). The authors indicate this method as being elective for enamel etching, in order to seal the pits and fissures. Another laser tested in this respect is the Nd:YAG laser. As in the case of CO<sub>2</sub> laser, studies connected with the use of Nd:YAG laser for enamel etching were focused on resistance tests to the traction of orthodontic resins (auto and photo-polymerized), as well as on those connected with the resistance to tearing, after fixation of the bracket on the dental surface.<sup>110-112</sup> Thus, for laser etching, approximately 15 impulses are necessary, of 75 mJ/impulse. The enamel surface must be covered with the accelerating solution for laser radiation. The area will be irradiated until the complete evaporation of the accelerator.<sup>113</sup>

Roberts-Harry,<sup>114</sup> using the Nd:YAG laser for enamel etching, considered that the etching model is inferior to that obtained with phosphoric acid, but much more targeted, and the working time is more reduced. The use of Nd:YAG laser in this purpose, is without any risk of pulpal involvement. Practically, the subjects did not show any symptoms, even 3 years from the treatment, responding normally to vitality tests. The working regime for Nd:YAG laser ( $\lambda = 1.06$  mm), is directed through a quartz optical fiber ( $f = 320$  nm). The power used reached approximately 1 W with 150 ms pulse duration. The studies of L. Corpas Pastor et al<sup>115</sup> add to the efficiency in laser conditioning with Nd:YAG laser; they recommend the use of laser power up to 2 W, 133 mJ/impulse, 15 Hz, and 60 s time of interaction. Presently, the Er:YAG laser ( $l = 2.96$  mm), tested by some researchers, is the most used laser in conditioning enamel surfaces.<sup>116</sup>

For esthetic reasons, orthodontic treatment with ceramic brackets is very frequently used nowadays. Problems regarding this treatment occur when the brackets are detached from the teeth, i.e., they can

lead to enamel fractures and ruptures in the brackets. Producers of ceramic brackets have modified their system of attachment with the adhesive, from a chemical to a mechanical one. The program has appeared with the testing and introducing of electro-thermal detaching. Strobl<sup>117</sup> and Tocchio<sup>118</sup> present the first data referring to the differences that occur during the process of *detaching the brackets* with CO<sub>2</sub> and YAG lasers. Tocchio et al have investigated the movements of detaching the poly-crystalline alumina brackets in comparison with those made of crystalline alumina. Separation was initiated by the application of a twisting force, two seconds from the irradiation. Practically, the thermal softening of the enamel represented the main mechanism. The laser induced heat to the labial surface of the bracket, and the temperature increase was transmitted through the bracket to the resin.

*Fibrotomy* is performed in the case of correction of teeth with exaggerate rotations, especially anterior maxillary and mandibular teeth, like the superior lateral incisors, in class II, subdivision 2. This fibrotomy maneuver is indicated after a slight hypercorrection of 3-5° was performed. We can use continuous CO<sub>2</sub> laser 1-3 W, but also Nd:YAG laser of 1.75-3 W. Continuous CO<sub>2</sub> laser of 5 W power is used. The incision line is precise, and the risk of infections is absent. Used in pulsed mode, CO<sub>2</sub> laser can also be used for etching the enamel surfaces of the uncovered tooth, in order to apply the anchorage bracket. The method is superior through the fact that etching of the enamel is also achieved in conditions of bleeding. We can also use the Nd:YAG laser, 20-30 impulses, with 1.75-3 W/impulse.

*Plaque gingivitis*,<sup>86</sup> as a direct consequence of retention of bacterial plaque in orthodontic patients, can benefit from laser therapy. The lasers reported as tested in this regard are CO<sub>2</sub> and Nd:YAG lasers, proving their ability to destroy bacterial plaque. The use of continuous CO<sub>2</sub> laser ( $\lambda = 10.6 \text{ mm}$ ), with a power of 1-2 W, in defocused position, may have a beneficial result in removing the bacterial plaque. In the specialized literature, the use of LLLT is quoted as a state-of-the-art method, such as the GaAlAs diode or the He-Ne laser.

In *plaque hyperplasia* and *surgical epulis* (following a non-sterile and imprecise uncovering of the canine), their removal can be done by laser sectioning. For gingival sectioning, Naumural and Benhatit use the CO<sub>2</sub> laser of 5 W (continuous mode). The advantages of the method consist of diminishing the bleeding and inflammation, precise incision, perfect visibility,

decrease of working time, sterile working conditions due to no contact with the instrument, rapid healing with no infections.

Bradley and Arcoria recommend the use of Nd:YAG laser, 20-30 impulses of 1.75-3 W/impulse, even without anesthesia. The advantage would be represented by the fact that, by using the laser fiber, it would determine very precise, fine, and painless sections. In this regard, White et al, based on a comparative study (scalpel-Nd:YAG laser), indicate the conditions that responded positively to laser therapy.

The bases for the method of *reducing the pain consequent to the orthodontic adjustment*, through LLLT, were set by Hong-Meng, Kenneth and David<sup>119</sup> from Singapore; the patients chosen for testing this therapy were aged between 21 and 24 years, presenting integral dental arches, with no open proximal areas, and with at least one premolar on each half arch. It was essential that no tooth presented conditions that could generate acute or chronic inflammations. The laser used was GaAlAs diode (class 3B, Laser System International, Egedalsvej, Vekso). Other low-energy laser systems, used in other investigations, include Panalax-4000 (Japan medical Laser Laboratory and Matsushita Electric Co., Tokyo, Japan), and Proton Plus (Ronvig Instruments, Daugaard, Denmark). The studies have led to the same conclusion: these lasers can determine the diminishing of pain consequent to the orthodontic adjustment. Beneficial results were obtained in the second and third day from the treatment. This result corresponds to clinical observations of specialists in orthodontics, who indicated the maximum of pain curve on day 3. Practically, using a GaAlAs laser probe, for 30-60 s, for 2-3 sessions, the pain can be greatly reduced, even completely removed.

## **LOW LEVEL LASER THERAPY (LLLT)**

The majority of practitioners only associate the use of laser in medicine with their applicability in surgery; however, nowadays there are numerous other well-known possibilities of pure use of laser in the medical art. One of the most controversial and exciting fields is that of biostimulating, the so-called low-energy level laser therapy (LLLT). After more than 20 years of experience in the use of LLLT in various medical fields, including dentistry, there was no case recorded in which LLLT had a negative effect.<sup>120-125</sup> This method is almost pain-free, sterile, and can be used by all

practitioners. Used correctly, it will lead to positive results in 60-90% of cases, with no side effects. Which other type of therapy has a similar offer? Nowadays, this therapy is well documented, and therefore it cannot be considered only a therapeutic alternative, but it becomes a self-standing technique with particularly beneficial results for a wide range of conditions.<sup>22</sup> In Japan, for instance, due to the in-depth scientific documentation, the medical scientific authorities have accepted the introduction of LLLT as scientific discipline, and those willing to embrace this medical therapeutic field must complete a 3-year course. The examples in this field are many.

## **CONCLUSIONS**

Throughout the years, new types of devices have emerged, and new conceptions regarding their use on various types of tissues. A few of the practitioners are aware of this new technology, but others continue to plead for conventional instruments. In the past, dental treatment offered a lot of reasons for a patient to avoid the specialty services: not understanding the necessity of a treatment, psychological discomfort, economic and social factors; however, the fact that the greatest issue was the "fear of pain" was scarcely discussed. From the moment the first extraction was accomplished, fear of pain dominated dentistry, becoming the obsession of patients, as well as the major preoccupation of dentists. More than any other cause, the fear of pain has become the source of professional stress. In the future, with the emergence of laser, patients will enjoy a better oral health, and will have more procedures available for improving their physiognomic aspect. None of the currently available lasers guarantees a total analgesia, but the present laser has taken an important step in this direction.

Application of laser radiation on soft tissues has constituted the first field of clinical use of laser in dentistry. In order to extend the applications in dentistry, researches should be based on the understanding of the effects of various wavelengths and other laser parameters on tissues. The laser of the future will probably be capable of producing a multitude of wavelengths and impulse durations, each specific for a certain application. When optimal parameters will be known, the ideal treatment will become a reality.

Scientific and medical researches, as well as the development of present systems, will define more and more clearly the field of use of laser radiation in dentistry, widening its therapeutic indications.

As it can be seen, there has been much progress

in the area of lasers in dentistry since the early report by Stern and Sognnaes. These early researchers and those who followed wished to develop clinical uses for lasers with the aim of bringing the lasers to the dental practitioner to improve dental care. The progression has been slow, and some of the ambitions of the early researchers have yet to be realized.

When the knowledge of what parameters are necessary for ideal treatment is a reality, lasers can be developed that can provide dentists with the ability to care for patients with improved techniques and equipment.

In conclusion, the emergence of various types of lasers constitutes an important event, which will change completely the manner of understanding and practicing dentistry.

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