Knowledge of the physical properties and interaction of laser with biological tissue in dentistry *

Conhecimento das propriedades físicas e da interação do laser com os tecidos biológicos na odontologia

Thiago Maciel Cavalcanti[1]
Maria Helena Chaves de Vasconcelos Catão[2]
Ruthinéia Diógenes Alves Uchôa Lins[4]
Renata Quirino de Almeida-Barros[1]
Ana Patrícia Aguiar Feitosa[3]

Abstract: The trend in dentistry is to incorporate less invasive methods to minimize pain and discomfort during and after dental intervention. Therefore, it is believed that laser therapy is an excellent treatment option, since it has beneficial effects for the irradiated tissues, such as activation of microcirculation, production of new capillaries, inflammatory and analgesic effects, in addition to stimulation of growth and cell regeneration. The comprehension of the interaction between lasers and tissue is based mainly on understanding the reactions that can be induced in those tissues by laser. This work intends to show how important it is to know the physical properties of laser as well as its interactions with biological tissues, since its effects and mechanisms of action are complex and are the object of various studies to better understand its forms of application and indications.
Keywords: Dentistry; Lasers; Physical properties; Tissues

Resumo: A tendência da odontologia é a incorporação de métodos menos invasivos com a finalidade de minimizar a dor e o desconforto durante e após as intervenções odontológicas. Por isso, acredita-se que a laserterapia seja uma excelente opção de tratamento, já que apresenta efeitos benéficos para os tecidos irradiados, como ativação da microcirculação, produção de novos capilares, efeitos anti-inflamatórios e analgésicos, além de estímulo ao crescimento e à regeneração celular. O entendimento da interação entre os lasers e os tecidos baseia-se principalmente no entendimento das reações que podem ser induzidas nesses tecidos pela luz laser. Este trabalho se propõe a mostrar a relevância do conhecimento das propriedades físicas do laser, bem como sua interação com os tecidos biológicos, considerando que os efeitos e os mecanismos de ação da luz laser são complexos e alvos de inúmeras pesquisas com vistas a um melhor delineamento de suas formas de aplicação e indicações.
Palavras-chave: Lasers; Odontologia; Propriedades físicas; Tecidos

Received on 04.10.2010.
Approved by the Advisory Board and accepted for publication on 27.12.2010.
* Work conducted at Universidade Estadual da Paraíba (UEPB) - Campina Grande (PB), Brazil
Conflict of interest: None / *Conflito de interesse: Nenhum*
Financial Support: None / *Suporte financeiro: nenhum*

[1] Dental Surgeon - M.Sc. in Dentistry, Universidade Estadual da Paraíba (State University of Paraiba - UEPB) - Campina Grande (PB), Brazil.
[2] PhD in Dentistry (Laser Use in Dentistry), Universidade Federal da Bahia (Federal University of Bahia - UFBA) - Professor, Graduate Program in Dentistry, Universidade Federal da Paraiba (Federal University of Paraíba - UEPB) - Campina Grande (PB), Brazil.
[3] MD - Graduated from Universidade Federal de Campina Grande (Federal University of Campina Grande - UFCG) - Physician, Programa Saúde da Família (Family Health Program) - Aroeiras (PB), Brazil.
[4] PhD in Oral Pathology, Universidade Federal do Rio Grande do Norte (Federal University of Rio Grande do Norte - UFRN) - Professor, Universidade Estadual da Paraíba (UEPB) - Campina Grande (PB), Brazil

INTRODUCTION

Laser is an acronym of the English language: Light Amplification by Stimulated Emission of Radiation, which precisely expresses how light is produced. It is electromagnetic radiation that differs from ordinary light for having a single wavelength, with its waves propagating coherently in space and time, carrying high concentrations of energy in a collimated and directional manner. [1]

The amount of interaction between lasers and tissue is generally determined by factors related to the laser and the optical characteristics of each tissue. However, the literature is very conflicting regarding the effects of lasers in these processes, making it difficult to identify specific effects of laser light because many factors and variables modify its effect on tissues. [2,3,4]

These factors are related to the optical (reflectance, absorption and scattering) and thermal (thermal conductivity and heat capacity) properties of the tissue, and to the wavelength, applied power, peak power, focus area (energy density and power) and exposure time of laser light. [4]

Laser radiation interacts with living matter through the processes of optical reflection, transmission, scattering and absorption. That is, upon reaching biological tissue, part of the light does not penetrate it, being thus reflected. The portion of light that penetrates the tissue will be divided into one part that will be absorbed, another that will be scattered and yet another that will be transmitted. [5]

Laser light, with its respective wavelengths, has been studied in various areas of dentistry, such as in cavity preparations, periodontics, bacterial reduction in root canal, biostimulation of soft tissue, and enamel conditioning. Several research studies have been conducted to establish the best parameters and irradiation techniques to enable the use of laser light in different dental procedures. [4]

Lasers can be broadly classified into high-power lasers or surgical lasers or HILT (High Intensity Laser Treatment) which have, for example, indications for surgery (cutting, coagulation, cauterization) and ablation effects (cavity preparations, prevention.), and into low power lasers or therapeutic lasers or LILT (Low Intensity Laser Therapy), widely used for therapeutic and biostimulating purposes, mainly acting as accelerators of healing processes. [1,6]

The different types of lasers are an important aid to professional practice in association with almost all dental specialties. Increasing interest in laser therapy by the scientific community has been noted due to the significant number of satisfactory results obtained with this kind of treatment.[7]

LITERATURE REVIEW

For a long time the sun was the only source of intense light known. [8] The use of light, pure energy, comes from ancient times, being known for some of its therapeutic properties, especially for fighting inflammation and painful processes. [9]

In 1917 Einstein explained the physical principles of stimulated emission, on which the phenomenon of laser is based. In 1960, Theodore H. Maiman built the first ruby laser emitter. Around 1961, the first laser surgery was performed, and in 1962 the first laser semiconductor was developed. In 1965, Sinclair and Knoll adapted this radiation to therapeutic practice; that same year, laser was used for the first time in dentistry by Stern and Sognnaes. [10]

Laser is a device that operates based on the phenomenon of population inversion, that is, absorption of energy so that most atoms become excited (electrons “jump” to more distant layers of the atomic nucleus). After population inversion, there must be a return to ground state with release of twin photons (coherent light). A similar process occurs with other primary sources of light, such as a light bulb, which, by Joule effect, has its energy converted into heat. Thermal energy promotes population inversion, but when electrons return to their stable configuration, photons are released with no phase relation (in various directions and with different frequencies). This process is called spontaneous emission. [11]

All laser equipment has three essential elements: (1) the laser medium, which can be of carbon dioxide, argon, helium-neon, YAG, excimers, dye, ruby and semiconductor diodes, such as gallium arsenide and aluminum (AsGaAl), among others; (2) the excitation source, which can be a *flash* lamp or an electric arc, will cause the molecules or atoms in the laser irradiation medium to transit from a resting to an excited state; return to the ground state causes the spontaneous emission of a photon and, finally, (3) two mirrors set at the two ends of a resonating chamber that reflect the light emitted back to the atoms or molecules in the laser medium. Therefore, the interaction of these three elements creates an emission of light that, upon reaching other molecules or atoms in the medium, eventually excites new electrons in smaller orbits. When these electrons return to the ground state, they release photons or new waves of light, which will reach other atoms at rest creating a chain reaction. [12]

The trend in dentistry is to incorporate less invasive methods to minimize pain and discomfort during and after dental treatment. Therefore, it is believed that laser therapy is an excellent treatment option, since it has beneficial effects for the irradiated tissues, such as activation of microcirculation, production of new capillaries, and anti-inflammatory and analgesic effects, in addition to stimulating growth and cell regeneration. [7]

O entendimento da interação entre os lasers e os tecidos, baseia-se principalmente no entendimento das reações que podem ser induzidas nestes tecidos pela luz laser. Cada tipo de laser resulta em luz de comprimento de onda específico, e cada comprimento de onda reage de uma maneira diferente com cada tecido. Outro fator importante é a densidade de energia, que é a quantidade de energia por unidade de área entregue aos tecidos. Temos também que considerar os fatores temporais, tais como: a forma de emissão de luz (contínua ou pulsátil), a taxa de repetição e a largura do pulso, para lasers de emissão pulsátil. [10,13]

The comprehension of the interaction between lasers and tissues is based mainly on understanding the reactions that can be induced in these tissues by laser light. Each type of laser results in light of specific wavelength, and each wavelength reacts differently with each tissue. Another important factor is energy density, which is the amount of energy stored in a given region of space per unit volume. We must also consider temporal factors, such as the form of light emission (continuous or pulsed), repetition rate and pulse width for pulsed laser emission. [10,13]

Todavia, além dos fatores inerentes do laser devemos observar as características peculiares de cada tecido, principalmente os que controlam as reações moleculares e bioquímicas, como o coeficiente de absorção do tecido, coeficiente de espalhamento, índice de refração do tecido, tipos de célula, perfusão sanguínea, condução térmica, oxigenação do tecido, inflamação, infecção ou necrose. [13]

However, in addition to the inherent factors of laser, we must observe the peculiar characteristics of each tissue, especially those that control molecular and biochemical reactions, such as tissue absorption coefficient, scattering coefficient, refractive index of tissue, cell types, blood perfusion, thermal conductivity, tissue oxygenation, inflammation, infection or necrosis. [13]

Laser radiation interacts with living matter through the processes of optical reflection, transmission, scattering and absorption. That is, upon reaching biological tissue, part of the light does not penetrate it, being thus reflected. The fraction of light that penetrates the tissue will be divided into one part that will be absorbed, another that will be scattered and yet another that will be transmitted. When light is absorbed, the resulting energy will generate photochemical and thermal effects, effects by photoablation, plasma-induced ablation and also photodisruption. [14]

In order to have clinical effect, it is necessary that the light be absorbed by the tissue (First Law of Photobiology - Grotthus-Draper Law). Light that is reflected, transmitted or scattered has no effect. The absorbed energy is measured in Joules/cm ^{2} and is known as energy density or fluence. The absorption of laser light depends on the amount of chromophore present in the tissue and whether the wavelength used corresponds to the absorption characteristics of that chromophore. Once absorbed, light can have three basic effects: photothermal, photochemical and photomechanical. The photothermal effect occurs when the chromophore absorbs energy with the corresponding wavelength and light energy is converted into heat capable of destroying the target that was hit. In the photochemical effect a chemical reaction occurs after light is absorbed by photosensitizing agents (endogenous or exogenous). This is the basic principle of photodynamic therapy. Thermal expansion can occur extremely fast and is capable of producing acoustic waves and photomechanical destruction of the tissue that absorbed it. [4,14]

The depth of penetration of laser energy in the tissues depends on absorption and dispersion. The dispersion of laser energy is inversely proportional to wavelength. The longer the wavelength, the deeper the penetration of laser energy. Wavelengths between 300 and 400 nm scatter more and penetrate less. Wavelengths between 1000 and 1200 nm disperse less and penetrate more. However, energy with a wavelength in the mid- and near-infrared range of the electromagnetic spectrum is superficially absorbed as the main chromophore in this wavelength is the water present in the tissue. [4]

Laser radiation has been used in surgical procedures to increase the surgical benefits, improving the clinical outcome. It offers some advantages, such as disinfection of the surgical area, no vibration, vaporization of the lesions, patient comfort, anti-inflammatory and biostimulating properties, accuracy in tissue destruction, minimal damage to adjacent tissues, hemostatic effect, reduction of pain and swelling, sterilization of the surgical area and the possibility of microscopic and endoscopic control. [15]

When we use laser in living tissue, we seek very specific clinical outcomes. The cell has a specific survival threshold; this depends on the tissue where it is located and also on its physiological state. If we use the laser considering the survival threshold of a given cell, we offer low energy, which will be used by the cell to stimulate its membrane and the membranes of its mitochondria. Therefore, we induce this cell to biomodulation, that is, the cell works seeking to normalize the affected region. In this case laser light works at a low power density. This type of therapy came to be called laser therapy, which uses low level laser for therapeutic purposes, obtaining photochemical effects. [16]

Some of the lasers used in dentistry are situated in the range of visible light (argon and some "therapeutic lasers") and others in the infrared range, thus invisible to the naked eye. [17]

The therapeutic properties of lasers have been studied since their discovery. The effects of their analgesic properties have been particularly observed in relation to chronic pain of various etiopathogenesis, from peripheral receptors to the stimulation of the central nervous system. Therefore, when laser light interacts with cells and tissue in the appropriate dosage, certain cell functions can be stimulated, such as stimulation of lymphocytes, activation of mast cells, increase in mitochondrial ATP production and proliferation of various cell types. [10]

Lasers in the infra-red range, at a wavelength of 632 to 780nm, are not able to cause tissue damage such as mutations and carcinogenesis and may be applied to the soft tissues of the oral cavity in the following cases: herpes, recurrent aphthous stomatitis (thrush), traumatic ulcers, burning mouth syndrome, and prevention and treatment of mucositis (Figures 1 and 2). [7,10]

Mucositis is the most common oral complication of cancer treatment, and it may be often necessary to pause or change treatment, which may influence the prognosis of the disease. This condition is an important cause of morbidity and even mortality in patients undergoing antineoplastic therapy. In these cases laser therapy provides pain relief, greater patient comfort, control of inflammation, maintenance of mucosal integrity and improved tissue repair. [18]

In herpes simplex and herpetic stomatitis, laser is important in the viral processes that involve immune factors. Laser action in these diseases produces an antiviral effect that is proportional to the stimulating effect of the patient's immune system. The best therapeutic response occurs in the prodromal stage and at the time of the appearance of vesicles. Laser radiation can weaken the microorganism, reducing symptoms, slowing progression of the disease and preventing recurrence of lesions in the same sites. Dosage should not be less than $4J/cm^2$ to prevent viral proliferation. The maximum energy per session should be 20J, 2 to 3 daily applications until the full healing of vesicles, as shown in Figure 3. [9,10]

The analgesic and anti-inflammatory action of laser light is considered an adjunct and not a definitive treatment, especially in patients with temporomandibular disorders (Figure 4). The therapeutic effects of lasers in the body are an alternative method in the treatment of teeth and soft tissue trauma, providing greater comfort to the patient shortly after dental trauma. [7,9]

Low-level intensity lasers (LLIT) or low-power lasers (LPL) can also be used to diagnose cavities with a laser that identifies optical behavioral differences between healthy and decayed tissue, to stimulate the formation of reparative dentin, to reduce dentin sen-

Figure 1: Application of laser in patients with recurrent aphthous stomatitis

Photo courtesy Prof.. Maria Helena C de V Catão

Figure 2: Patient with burning mouth syndrome

Photo courtesy Prof.. Maria Helena C de V Catão

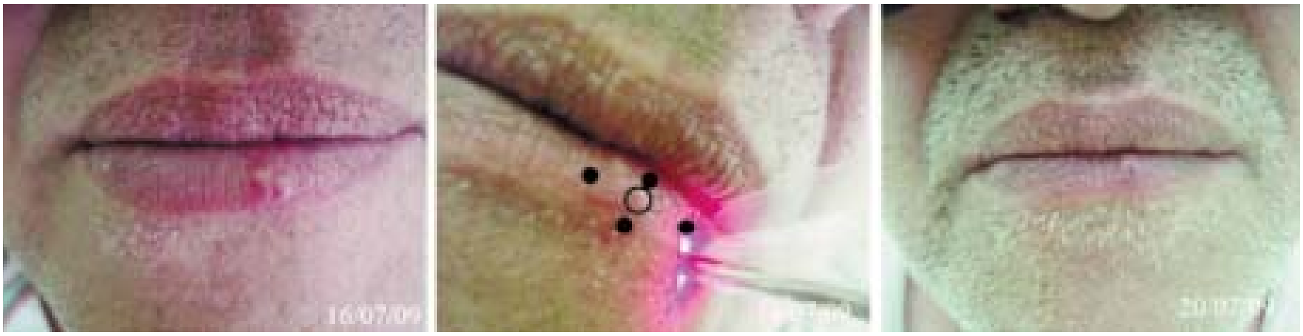

FIGURE 3: Application of red laser (AsGaAl) 4J/cm 2 in each of the five points (according to the scheme) in a patient with herpes labialis in the vesicular phase, resulting in healing of the lesion after four days

Photo courtesy Prof.. Maria Helena C de V Catão

sitivity and pain in cases of hyperemia, to aid in anesthesia in cases of severe pulpitis, to promote faster bone repair in the periapical region and less bleeding and edema in cases of gingivitis and periodontitis, and to reduce painful symptoms in burning mouth syndrome, alveolitis, temporomandibular disorders (TMD), and mucositis and pericoronitis. [8,19,20]

The use of low intensity laser in pericoronitis benefits the patients in terms of pain relief, reducing their symptoms. It also helps to control inflammation and reduce edema, often with no need for systemic medication due to the therapeutic effects of laser (Figure 5). [21,22]

Laser at a very high level of energy to the point that this energy is transformed into heat damage and exceeds the survival threshold of the cell, leading to lysis and consequently cell death, is called surgical laser or HILT. [6]

Surgical laser acts on the target tissue. The effects of these actions can be divided into photothermal (coagulates, carbonizes, and vaporizes), phootomechanical acoustic (cuts with precision), photoablative (destroys to disrupt) and photoionizing (DNA breakage). [13]

Laser therapy has been used for over 30 years and over 90% of the available literature reports positive effects. However, unfavorable results can occur due

FIGURE 4: Patient with temporomandibular disorder

Photo courtesy Prof.. Maria Helena C de V Catão

FIGURE 5: Application of AsGaAl laser (630nm) in a patient with pericoronitis

Photo courtesy Prof.. Maria Helena C de V Catão to the use of low or high doses, misdiagnosis, insufficient number of sessions, and lack of standardization of the frequency of applications. In fact, the consecration of laser as a therapy requires knowledge of the energy used, investigation of the effects it produces in the body and the employment of a correct methodology. [7]

FINAL CONSIDERATIONS

The constant search for bio-psycho-social balance by human beings requires the insertion of new and effective therapies into the modern and broad area of dentistry. Hence, new research studies in laser technology suggest new ways and techniques of its use by surgeon dentists. The physical fundamentals and the interaction of laser light with tissues must be clarified and known by these professionals, enabling different research and consolidating laser therapy as a treatment option in dental practice. ❑

REFERENCES

1. Castilho Filho T. Avaliação da ação da radiação laser em baixa intensidade no processo de osseointegração de implantes de titânio inseridos em tíbia de coelhos [dissertação]. São Paulo (SP): Instituto de pesquisa energéticas nucleares da Faculdade de odontologia da Universidade de São Paulo; 2003.64 p.
2. Carevalli CMM. Efeito da radiação do diodo laser (830nm) em cultura de fibroblastos (CHO-K1) [dissertação]. São Paulo (SP): Universidade do Vale do Paraíba; 2001.69 p.
3. Ladalardo TC, Pinheiro A, Campos RA, Brugnera Jr A, Zanin F, Albernaz PL, et al. Laser therapy in the treatment of dentine hypersensitivity. Braz Dent J. 2004;15:144-50.
4. Moriyama LT. Ablação de resinas compostas com laser de Er: YAG sob diferentes fluxos de água [dissertação]. São Paulo (SP): Instituto de física de São Carlos da Universidade de São Paulo; 2006. 85 p.
5. Pinheiro ALB, Brugnera Jr A, Zanin FAA. Aplicação do laser na odontologia. In: Pinheiro ALB. Interação tecidual. São Paulo: Editora Santos; 2010. p.77-89.
6. Araújo GS. Avaliação histológica do efeito do laser de baixa intensidade na resposta do tecido conjuntivo ao cimento endofill. [tese]. São Paulo (SP): Faculdade de Odontologia de Araraquara da Universidade Estadual Paulista; 2008. 84 p.
7. Henriques ACG, Maia AMA, Cimões R, Castro JFL. A laserterapia na odontologia: propriedades, indicações e aspectos atuais. Odontologia Clín Científ. 2008;7:197-200.
8. Lascala NT, Moussalli NH. Compêndio terapêutico periodontal. 3. ed. São Paulo: Artes Médicas, 1999. Capítulo14, Laserterapia em periodontia; p.293-307.
9. Genovese JW. Laser de baixa intensidade: aplicações terapêuticas em odontologia. São Paulo: Lovise Ltda, 2000. 175p.
10. Catão MHCV. Os benefícios do laser de baixa intensidade na clínica odontológica na estomatologia. Rev Bras Patol Oral. 2004;3:214-8.
11. Mendonça PEMF. O Laser na biologia. Rev Bras Ens Fis.1998;20:86-94.
12. Renisch L. Laser physics and tissue interactions. Otolaryngol Clin North Am. 1996; 29:893-914.
13. Chavante MC. Laser em bio-medicina: Princípios e prática. São Paulo: Ed Atheneu; 2009. p.87.
14. Yoshiyasu RYA. Um estudo in vitro sobre os efeitos da irradiação pelo laser de Er: YAG combinado com a terapia com flúor na resistência ácida do esmalte de dentes submetidos a aparelho ortodôntico fixo. [dissertação]. São Paulo (SP): Instituto de Pesquisas Energéticas Nucleares da Faculdade de odontologia da Universidade de São Paulo; 2001.83 p.
15. Gomes ASL, Lopes MWF, Ribeiro CMB. Radiação laser: aplicações em cirurgia oral. Int J Dent. 2007;6:17-20.
16. Vo-Dinh, editor. Biomedic Photonic Handbook. Boca Raton (FL): CRC Press; 2003. Chapter 48, Low-power laser therapy; p.1-26.
17. Almeida-Lopes L, Massini RJ. Lasers e suas aplicações. São Paulo: DMC Equipamentos, 2000. 31p.
18. Kelner N, Lisboa de Castro JF. Laser de baixa intensidade no tratamento da mucosite oral induzida pela radioterapia: relato de casos clínicos. Rev Bras Cancerol. 2007;53:29-33.
19. al-Khateeb S, ten Cate JM, Angmar-Månsson B, de Josselin de Jong E, Sundström G, Exterkate RA, et al. Quantification of formation and remineralization of artificial enamel lesions with a new portable fluorescence device. Adv Dent Res. 1997;11:502-6.
20. Castro JFL. Oncologia Oral. Recife: Ed. Universitária UFPE; 2005. 253p.
21. Catão MHCV, Costa LJ. Tratamento da pericoronarite com laser terapêutico - Caso clínico. RGO. 2004;52:175-86.
22. Catão MHCV, Gerby MEM, Gonçalves RC. A Laserterapia no tratamento da radiomucosite em paciente com carcinoma espino celular no palato mole: relato de caso. Laser Dental Show. 2003;8-9.

MAILING ADDRESS / ENDEREÇO PARA CORRESPONDÊNCIA:
Thiago Maciel Cavalcanti
Rua Abel Costa, 463
Bairro Universitário
58429-050 Campina Grande, PB, Brazil
Phone: (83) 3333-3111
E-mail: thiagomaciel_cg@hotmail.com

How to cite this article/*Como citar este artigo*: Cavalcanti TM, Almeida-Barros RQ, Catão MHCV, Feitosa APA, Lins RDAU. Knowledge of the physical properties and interaction of laser with biological tissue in dentistry. An Bras Dermatol. 2011;86(5):955-60.