ISSN 1855-9913

# Case Studies on the Use of a New Flat-top Handpiece for Biomodulation in Dentistry and Medicine

**Alberico Benedicenti[1], Andrea Amaroli[2], Wayne Seting[1], Alex Mathews[1], Stefano Benedicenti[1]***

*[1]University of Genoa, Department of Surgical Sciences and Integrated Diagnostic; Largo R. Benzi 10 - 16132 Genoa, Italy*
*[2]University of Genoa, Dipartimento di Scienze della Terra, dell'Ambiente e della Vita (DISTAV); Corso Europa 26 - 16132 Genoa, Italy*

**Corresponding author: Stefano Benedicenti -University of Genoa, Department of Surgical Sciences and Integrated Diagnostic; Largo Rosanna Benzi 10, 16132 Genova, Italy. Tel 00390103537309, email: benedicenti@unige.it*

## ABSTRACT

Photobiomodulation (PBM) has been used in clinical practice for more than 40 years and its action mechanisms on the cellular and molecular levels have been studied for about 30 years.

Little is known about the use of Nd:YAG for biomodulation. The aim of this study is to present a series of case reports on dental and medical applications of a new flat-top handpiece for Nd:YAG.

**Key words:** Laser; Photobiostimulation; Photobiomodulation, flat-top handpiece.

*Article: J. LA&HA, Vol. 2015, OnlineFirst*
*Received: February 11, 2015; Accepted: July 27, 2015*



## I. INTRODUCTION

Photobiomodulation (PBM) is the term applied to the manipulation of cellular behavior using low intensity light sources and works on the principle of inducing a biological response through energy transfer [1]. PBM has been used in clinical practice for more than 40 years and its mechanisms of action at the cellular and molecular levels have been studied for about 30 years [2]. Photonic energy delivered into the tissue modulates biological processes within that tissue and within the biological system of which that tissue is a part [3]. It is generally accepted [4,5] that the mitochondria of eukaryotic cells are the initial absorption sites for laser radiation in the visible-to-near IR optical region and cytochrome c oxidase is the responsible photoreceptor.

The most frequently used mechanism of photon energy conversion in laser medicine is heating. Very significant heating of irradiated samples occurs with all methods of tissue destruction (cutting, vaporization, coagulation, ablation), but at low-light intensities the photochemical conversion of the energy absorbed by a photoreceptor prevails. So, in order to produce photobiomodulation, it is necessary to keep the thermal increase under control and avoid a thermal increase of more than 4-5 degrees [6].

In clinical applications, photobiomodulation has been used to successfully induce wound and bone healing [7,8,9,10], pain reduction and [11] anti-inflammatory effects [12,13,14].

With regard to the wavelength of lasers, little is known about the use of the neodymium-doped yttrium aluminum garnet (Nd:YAG) as a biostimulator. Most investigations have centered on the use of laser energy in the range from 400 nm to 980 nm. In this range of wavelengths, photons can penetrate effectively to reach deeper structures. Nd:YAG, at a wavelength of 1064 nm, is near this window and exhibits some advantages. In terms of penetration of the radiation, longer wavelengths, such as the (infrared) diode laser or Nd:YAG laser, penetrates deeper, whereas laser energy with a shorter wavelength, such as red light produced using the He–Ne laser, penetrates less deeply [15].

Recently Gutknecht et al. [16] demonstrated that low-level Nd:YAG laser therapy accelerates the wound healing process by changing the expression of PDGF and bFGF, genes responsible for the stimulation of the cell proliferation and fibroblast growth, whereas there were no statistically significant differences among the groups using other laser wavelengths (660 nm, 810 nm, 980 nm).

Significant effort has been made to clarify parameters of deposited energy density that will effectively promote positive change in individual cells while avoiding negative effects. Karu observed that high fluences cause destruction of photoreceptors, which is accompanied by growth inhibition and cell lethality [17]. Other researchers have also demonstrated that irradiation with fluences higher than 10 J/cm2 damages

DNA [18,19]. Finally, Bensadoun suggested the optimal dose in the range of 2–3 J/cm2 for prophylaxis and not more than 4 J/cm2 for therapeutic effects and the application of a single spot on a lesion rather than a scanning motion over the entire lesion [20]. The World Association of Laser Therapy (WALT) has stated that applying energy in the range from 3 J/cm2 to 10 J/cm2 will promote effective biostimulation while avoiding bio-inhibitory effects. [21]

While this range of energy density seems well documented, achieving this goal is problematic. The energy must reach target cells at this level to be effective. A method of delivering photons to a group of individual cells, often deep within a tissue mass, in a uniform and predictable manner has been lacking. Laser energy density and distribution at the tissue surface is a poor predictor of deeper tissue distribution.

Several problems complicate the adoption of a standardized protocol. While the biostimulatory effect of laser energy is experienced on a cellular level, the energy is applied macroscopically to large volumes of tissue in a non-uniform manner. As energy passes through tissue, part of it is absorbed so each successive depth of cells is irradiated differently. Beers law is usually used to define this relationship. However, this is inadequate since the dominant form of interaction at wavelengths between 600 nm and 1400 nm is scattering [22]. Thus as energy enters tissue, its density decreases rapidly.

The output of most clinical lasers is Gaussian in profile. Therefore, cells directly in the center of the beam are irradiated at a very high fluence, while those on the periphery of the incident beam receive a very low dose. As a result, cells at the beam center may be overstimulated far above the scientifically recommended range of 3-10 J/cm2 and therefore inhibited, while those on the periphery receive insufficient cellular energy to produce any effect.

Further complicating the goal of standardization is the issue of beam divergence. Fiber delivered laser energy exits the fiber with a significant divergence, usually on the order of 8 degrees. The applied energy is, therefore, distributed over an increasing area as the tip-to-tissue distance increases, dramatically affecting energy density at a cellular level. At currently reported beam divergences, energy density can be diminished by 90 percent with only 3 millimeters of tip-to-tissue distance. This makes the repeatable application of an appropriate energy density extremely technique-sensitive and operator-sensitive.

As a result of these problems, a new handpiece was developed that provides homogeneous irradiation over a 1 cm2 surface and has the same irradiation area (spot size) from contact up to 135 cm of distance from the target tissue. With the introduction of a new flattop handpiece [14], it is now possible to irradiate a target surface with homogenous energy density, using relatively high power densities, in less time and without any risk of thermal damage. This would make the application repeatable and not operator sensitive [14,23].

The aim of this study is to present a preliminary clinical report on dental and medical applications of a new flat-top handpiece for Nd:YAG (Genova™ handpiece-Fotona-Slovenia), according to the therapeutic protocols described in Benedicenti's textbook [24].

Clinical parameters were determined following recently published research protocols [23,25]. The MSP modality with a power of 0.5 W, 10 Hz with an application every other day produced the best results in terms of endogenous ATP production.

## II. MATERIALS AND METHODS

### a) Case 1: Wound healing

Abscess of the left mandible on a cat.

The irradiation protocol was: one session every other day for 8 applications using the Genova™ handpiece (Nd:YAG flat-top) at 0.5 W, 10 Hz in MSP modality, one minute per point with 5 points of irradiation: 4 points on the peripheral area and 1 in the center of the lesion (Fig. 1-5).

Fig. 1-5: Abscess of the left mandible on a cat

**b) Case 2: Wound healing in human patient**

In case of aphthous lesions, one or two laser applications would immediately give relief from pain and promote fast healing.

The parameters are: Genova™ handpiece (Nd:YAG flat-top) at 0.5 W, 10 Hz in MSP modality, 1 minute per spot (1 cm2) (see Figs. 6 and 7).

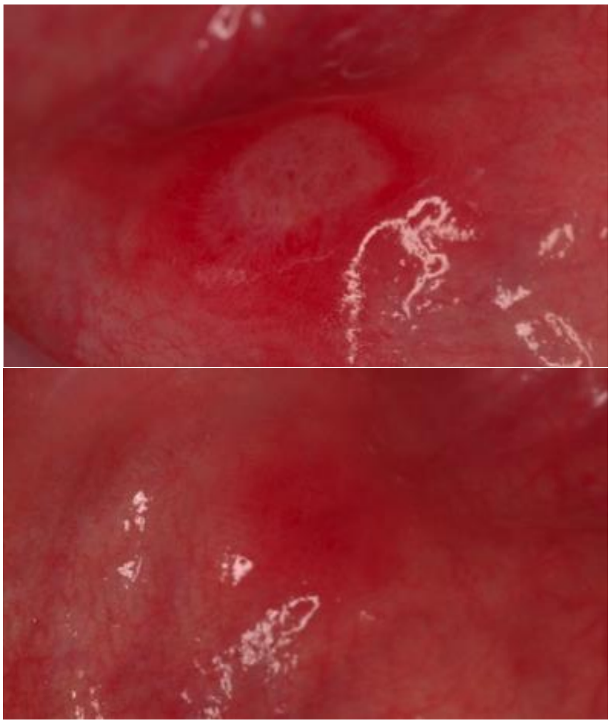

Fig. 6-7: Wound healing in human patient

**c) Case 3: Mucosa and bone healing (courtesy of Dr. Luca Lancieri)**

For extractions, the Genova™ handpiece (Nd:YAG flat-top) can be used to speed up the mucosa and bone healing process (Figs. 8-12). After the surgery the area is irradiated with the same parameters: 0.5 W, 10 Hz in MSP modality, 60 seconds per 1 cm2 from the buccal and occlusal side, for five sessions every other day. The post-operative pain and swelling is reduced, and after only two months, the final X-ray shows good bone healing (Figs. 13 and 14).

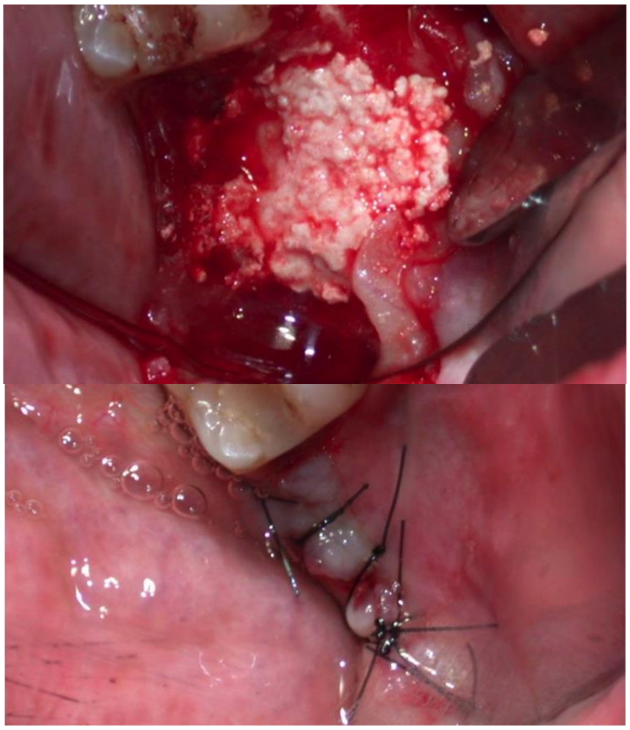

Fig. 8-12: Mucosa and bone healing process.

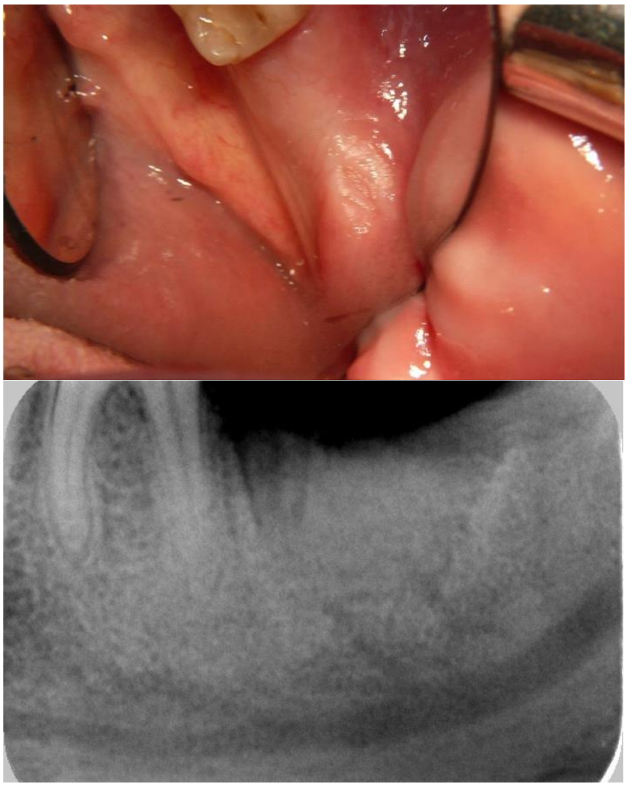

Fig. 13-14: Bone healing after two months.

### d) Case 4: Pain reduction and implant osseointegration (courtesy of Dr. Alberto Rebaudi)

In this case involving an immediate post-extractive implant, the laser has been used to reduce post-operative pain, swelling and to speed up the osseointegration of the implant as suggested by Ebrahimi [25].

The clinical situation before the surgery is shown in Figs. 15, 16. After the surgery (Figs. 17-19) the area is irradiated with the same parameters (0.5 W, 10 Hz in MSP modality, 60 seconds per 1 cm2 from the buccal and occlusal side, for five sessions every other day.

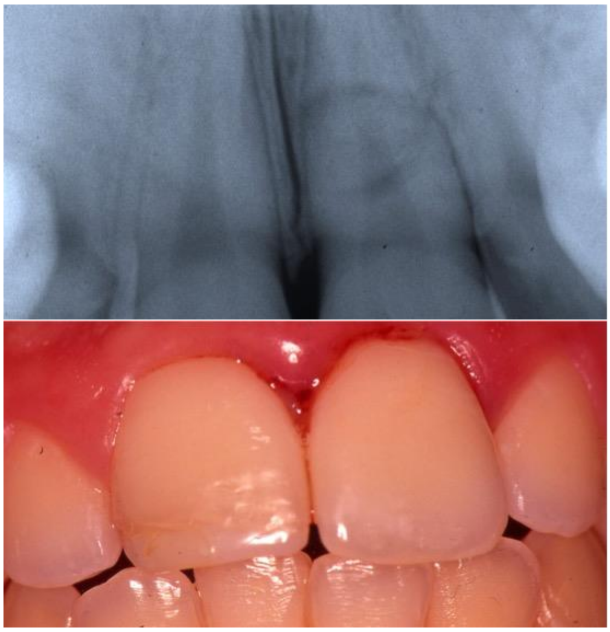

Fig. 15, 16: The clinical situation before the surgery

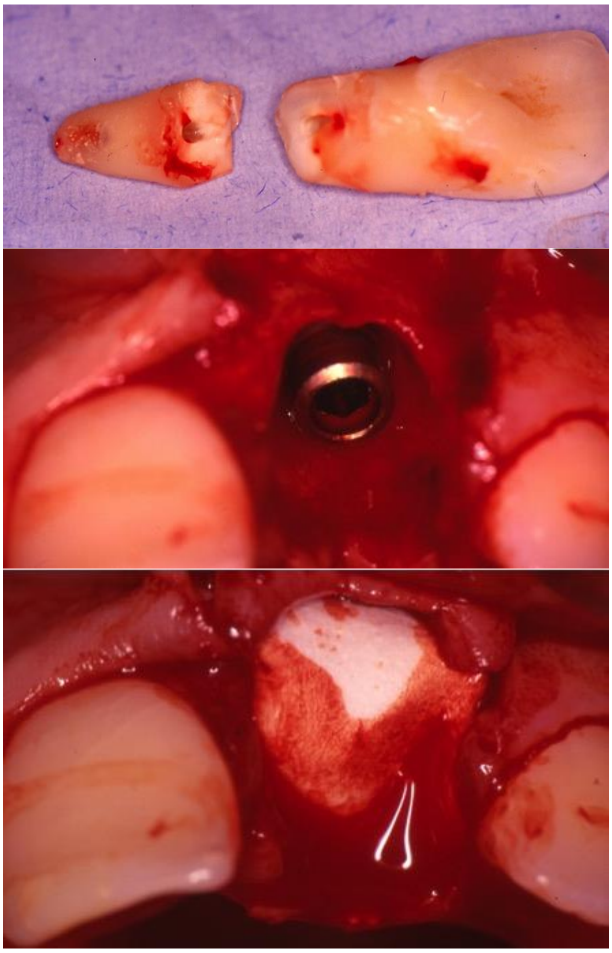

Fig. 17-19: After the surgery

The follow up after two months shows an acceptable osseointegration of the implant (Fig. 20) that increases after six months (Fig. 21).

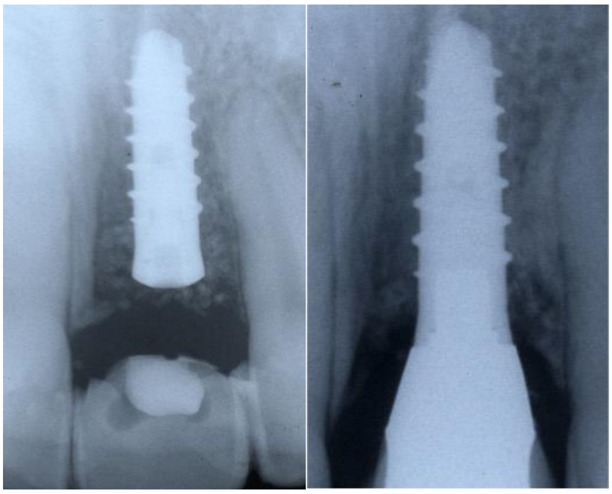

Fig. 20, 21

e) **Case 5: Pain reduction and anti-inflammatory effect**

The patient, after a horsefly bite, presented a severe pain and swelling (Fig. 22). After three sessions every other day with the Genova™ handpiece (Nd:YAG flat-top) with the following parameters: 0.5 W, 10 Hz in MSP modality, 60 seconds per 1 cm2 (following the scheme presented in Fig. 23), the patient reported no pain and a significant reduction in swelling (Fig. 24).

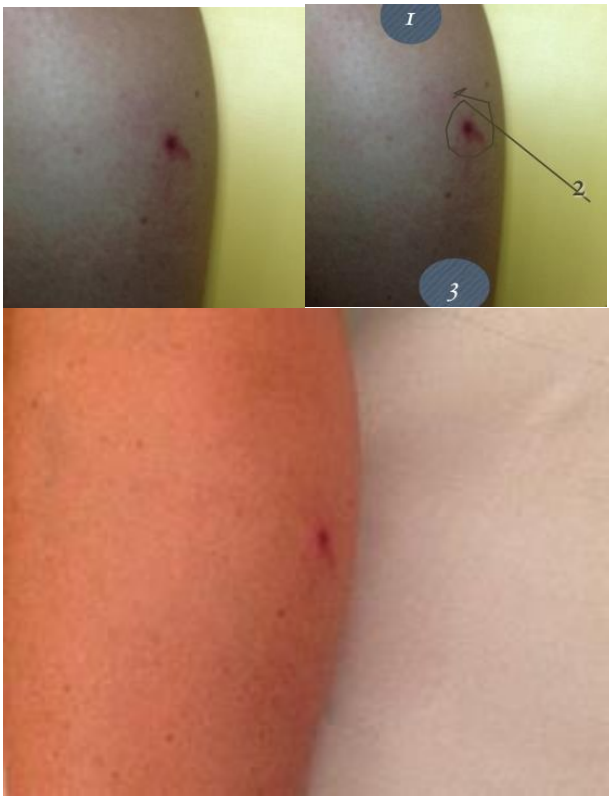


Fig. 22-25: Improvement after three sessions every other day

f) **Case 6: Pain reduction**

The patient had a previous anterior cruciate ligament surgery with residual swelling, reduced mobility and pain (Fig. 25).

Fig. 25

The laser irradiation was performed every other day with the Genova™ handpiece (Nd:YAG flat-top) 0.5 W, 10 Hz in MSP modality, 60 seconds per 1 cm2 and six points of irradiation (Fig. 26).


Fig. 26: Six points of irradiation

Fig. 27: The result after 14 days / 7 applications

## III. CONCLUSIONS

Within the limitations of this study, it can be concluded that:

1) Nd:YAG laser, because of its high penetration, seems to be an ideal wavelength for biomodulation.

2) With the Genova™ flat-top handpiece, the irradiation is distributed homogenously compared to a conventional defocused handpiece with a Gaussian profile, while using relatively high power densities in less time and without any risk of thermal damage if proper parameters are used.

3) The homogeneous irradiation is distributed over a 1 cm2 surface, from contact up to 135 cm of distance from the target tissue. This would make the application repeatable and not operator-sensitive.

## REFERENCES


1. J. Turner, L. Hode, The new laser therapy handbook, Prima books, Granges berg, Sweden, 2010.
2. T. Karu, Is it time to consider photobiomodulation as a drug equivalent?, Photomed. Laser Surg. 31 (2013) 1-3. Doi: 10.1089/pho.2013.3510.
3. T. Karu, The Science of Low-Power Laser Therapy. Gordon & Breach Science Publishers, (1998).
4. Benedicenti S, Pepe IM, Angiero F, Benedicenti A (2008) Intracellular ATP level increases in lymphocytes irradiated with infrared laser light of wavelength 904 nm. Photomed Laser Surg. 26(5):451-453.
5. Passarella S, Karu T. (2014) Absorption of monochromatic and narrow band radiation in the visible and near IR by both mitochondrial and non-mitochondrial photoacceptors results in photobiomodulation. J Photochem Photobiol B. Nov;140:344-58.
6. Albrektsson T, Eriksson A. (1985) Thermally induced bone necrosis in rabbits: relation to implant failure in humans. Clin Orthop Relat Res. May;(195):311-2.
7. Webb C, Dyson M, Lewis WHP (1998) Stimulatory effect of 660 nm level laser energy on hypertrophic scar derived fibroblasts: possible mechanisms for increase in cell counts. Lasers Surg Med 22:294–301.
8. Agaiby AD, Ghali LR, Wilson R, Dyson M (2000) Laser modulation of angiogenic factor production by T Lymphocytes. Lasers Surg Med 26:357–363.
9. Leung MC, Lo SC, Siu FK, So KF (2002) Treatment of experimentally induced transient cerebral ischemia with low energy laser inhibits nitric oxide synthase activity and upregulates the expression of transforming growth factor-Beta. Lasers Surg Med 31:283–288.
10. Medrado AR, Pugliese LS, Reis SR, Andrade ZA (2003) Influence of low-level laser therapy on wound healing and its biological action upon myofibroblasts. Lasers Surg Med 32:239–244.
11. Guzman, J., Esmail, R., Karjalainen, K., Malmivaara, A., Irvin, E., Bombardier, C. (2001) Multidisciplinary rehabilitation for chronic low back pain: systematic review. BMJ 322: 1511-1516.
12. Ailioaie C, Lupusoru-Ailioaie L (1999) Beneficial effects of laser therapy in the early stages of rheumatoid arthritis onset. Laser Ther 11(2):79–87.
13. Hsieh RL, Lee WC (2014) Short-term therapeutic effects of 890-nanometer light therapy for chronic low back pain: a double-blind randomized placebo-controlled study Lasers Med Sci 29:671–679.
14. F. Vallone, S. Benedicenti, E. Sorrenti, I. Schiavetti, F. Angiero, Effect of diode laser in the treatment of patients with nonspecific chronic low back pain: a randomized controlled trial, Photomed. Laser Surg. 32 (2014) 490-494. Doi: 10.1089/pho.2014.3715.
15. Cameron MH, Perez D, Otaho-Lata S (1999) Electromagnetic radiation. In: Cameron MH (ed) Physical agents in rehabilitation: from research to practice. Saunders, Philadelphia, pp 303–344.
16. Usumez A, Cengiz B, Oztuzcu S, Demir T, Aras MH, Gutknecht N.(2014). Effects of laser irradiation at different wavelengths (660, 810, 980, and 1,064 nm) on mucositis in an animal model of wound healing. Lasers Med Sci.29(6):1807-13.
17. Karu T (2002) Low-power laser effects. In: Waynant RW (ed) Lasers in medicine. CRC, Boca Raton, pp 171–210.
18. Hawkins D, Abrahamse H (2007) Influence of broad-spectrum and infrared light in combination with laser irradiation on the proliferation of wounded skin fibroblasts. Photomed Laser Surg 25:159–169.
19. Houreld N, Abrahamse H (2007) In vitro exposure of wounded diabetic fibroblast cells to a Helium–Neon laser at 5 and 16 J/cm2. Photomed Laser Surg 25:78–84.
20. Bensadoun RJ, Nair RG (2012) Efficacy of low-level laser therapy (LLLT) in oral mucositis: what have we learned from randomized studies and meta-analyses? Photomed Laser Surg 30:191–192.
21. World Association of Laser Therapy. Recommended treatment doses for low level laser therapy. Available at: Http//www.walt.nu
22. Beer (1852) "Bestimmung der Absorption des rothen Lichts in farbigen Flüssigkeiten" (Determination of the absorption of red light in colored liquids), Annalen der Physik und Chemie, vol. 86, pp. 78–88.
23. A. Amaroli, S. Parker, G. Dorigo, A. Benedicenti, S. Benedicenti (2015), Paramecium: a promising non-animal bioassay to study the effect of the 808 nm infra-red diode laser photobiomodulation, Photomed Laser Surg. Jan;33(1):35-40.
24. Benedicenti A. (2005) Atlas of laser therapy, 3rd ed , Teamwork Media-Villa Carcina (BS) Italy.
25. Amaroli A, Ravera S, Parker S, Panfoli I, Benedicenti A, Benedicenti S. (2015) Effect of 808 nm Diode Laser on Swimming Behavior, Food Vacuole Formation and Endogenous ATP Production of Paramecium primaurelia (Protozoa). Photochem Photobiol. Jun 28. doi: 10.1111/php.12486.
26. The influence of low-intensity laser therapy on bone healing. (2012) Ebrahimi T, Moslemi N, Rokn A, Heidari M, Nokhbatolfoghahaie H, Fekrazad R. J Dent. 9(4):238-48.