Some aspects of the use of the Nd:YAG laser in periodontal therapy

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Fig. 1a


Fig. 1b

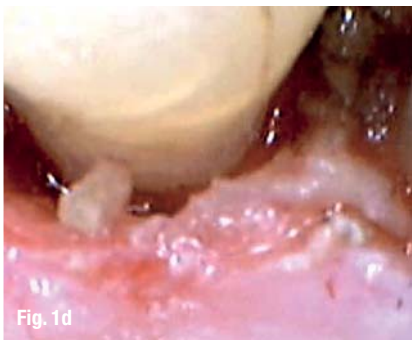
Fig. 1a_X-ray.
Fig. 1b_The situation before treatment.

_Introduction

Moderate forms of periodontitis are demonstrated in 50 to 90 % of adults with regional and age-based differences. Periodontitis destroys the integrity of oral mucous membranes and is one of the main reasons for tooth loss, especially amongst people aged 40 and older. Aggressive forms of periodontitis may result in advanced loss of periodontal attachment and alveolar bone, resulting in urgent need for prosthetic treatment for those individuals within a very short time. The presence of bacteria in the gingival sulcus and periodontal tissues is a determining factor of the development of periodontal disease. The conventional periodontal therapy aims to suppress inflammatory signs and pathogenic bacteria. This therapy consists of root scaling and planing, whether associated with antibiotic chemotherapy or not. In areas of different access such as the furcations, invaginations and concavities, the use of manual curettes or ultrasound does not ensure the eradication of periopathogenic bacteria and the success of treatment. Moreover, the increase of strains capable of resisting antibiotic chemotherapy may also damage the efficacy of conventional periodontal treatment. Based on these facts, alternative methods are being studied with the aim of achieving a more efficient therapy with more predictable prognosis. In this regard, lasers have become an interesting adjuvant therapy with promising results. The scientific base for this approach to treating periodontitis is still not entirely evidence based and more studies are needed to determine its effectiveness and optimal parameters. The present article will provide a summary of our experiences and the outcome of four clinical studies.

Fig. 1c_After creating the funnel.
Fig. 1d_The post-op situation.

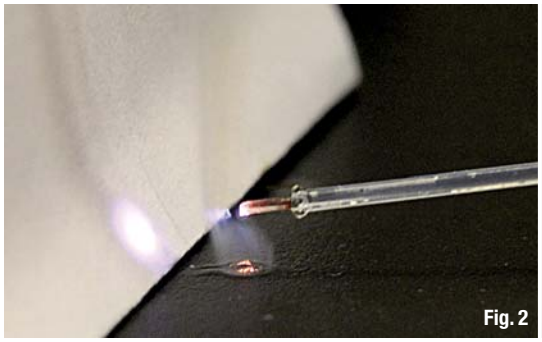

Fig. 1c


Fig. 1d

_The dental Nd:YAG laser

Modern dental Nd:YAG lasers are free running and pulsed as opposed to other continuous wave lasers with gated pulse options. The ablation ability is set either by increasing the output power or the pulse repetition rate. The therapy is performed in tissue contact and in constant motion.

For pulsed lasers, peak power has an order of magnitude higher than an average power. There are very high spikes, with peak power being 1,000 times higher than average power, and relatively long rest periods. Pulse width (the amount of time for each pulse) varies from 90 to 1,200 microseconds in different pulsed Nd:YAG lasers and is an important component of this


Fig. 2

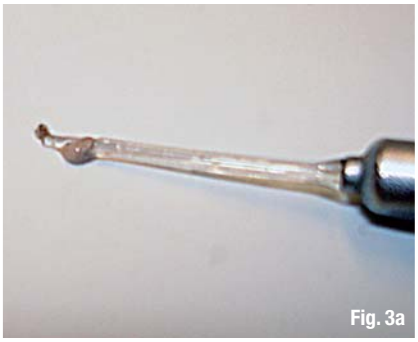

Fig. 3a


Fig. 3b

technology. The short duration allows for a long resting time, which sometimes obviates the need for local anaesthesia. The number of pulses (frequency, pulse repetition rate) per second is one of the crucial factors in pulsed Nd:YAG lasers. With a high repetition rate of 10 to 100 Hz in different devices, one can achieve smoother cutting at a very low power setting because the peak power in each pulse can be very high (White *et al.* 1994).

The 1,064 nm wavelength is invisible, which makes the evaluation of the actual effected area difficult. Seen through an infra-red camera, it is obvious that the light is spread like a small ball over a rather large area and not just around the fibre tip.

The Nd:YAG laser energy is absorbed by tissue and it is this absorbance that allows surgical excision and coagulation of tissue. The absorption in different dental tissues shows a low absorption and a moderate absorption for hydroxyapatite. The ablative effect of this wavelength on hard dental tissue is obviously rather low. Its wavelength has a particular affinity for melanin or other dark pigments. Therefore, microbes with dark pigment are more sensitive to this laser. These microbes can be eliminated at rather low power settings at which there will be no collateral damage to the adjacent tissue. The choice of wavelength is important when it comes to bactericidal effect.

Harris (2004) aimed to develop a method for quantifying the efficacy of ablation of *Porphyromonas gingivalis in vitro* with two different lasers. The ablation thresholds for the two lasers were compared in the following manner. "The energy density was measured as a function of distance from the output of the fibre-optic delivery system. *P. gingivalis* cultures were grown on blood agar plates under standard anaerobic conditions. Blood agar provides an approximation of gingival tissue for the wavelengths tested in having haemoglobin as a primary absorber. Single pulses of laser energy were delivered to *P. gingivalis* colonies and the energy density was increased until the appearance of a small plume was observed coincident with a laser pulse. The energy density at this point defines the ablation threshold. Ablation thresholds for a single pulse were determined for both *P. gingivalis* and for blood agar alone. The large difference in ablation thresholds between the pigmented pathogen and the host matrix for pulsed-Nd:YAG indicated a significant therapeutic ratio and *P. gingivalis* was ablated without visible effect on the blood agar. Near threshold, the 810 nm diode laser destroyed both the pathogen and the gel. The pulsed Nd:YAG, however, may selectively destroy pigmented pathogens, leaving the surrounding tissue intact. The 810 nm diode laser may not demonstrate this selectivity owing to its longer pulse length and greater absorption by haemoglobin" (Harris 2004).

_Which microbes are eliminated?

It is postulated that the Nd:YAG laser eliminates primarily the dark-pigmented microbes, such as *P. gingivalis*, whereas *Aggregatibacter actinomycetemcomitans*, having no pigments, would not be similarly reduced. However, in Andrade et al. (2008) *A. actinomycetemcomitans* was eliminated directly after irradiation, but regained approximately 50 % of the baseline level after six weeks. Such recurrence is reported in several studies and is attributed to cross-contamination from non-treated pockets and/or saliva (Teughels et al. 2000). *A. actinomycetemcomitans* is found in 90 % of all cases of juvenile periodontitis but only in 50 % of adult chronic periodontitis (Slots et al. 1980). *P. gingivalis* is reported to be aggregated with other periodontal pathogens, such as *Prevotella intermedia* so light absorption into the dark pigment of *P. gingivalis* is likely to cause consid-

Fig. 2_Lateral distribution of the light.
Figs. 3a–d_The fibre with water cooling, easy to clean (3a–b) and without water cooling (3c–d).

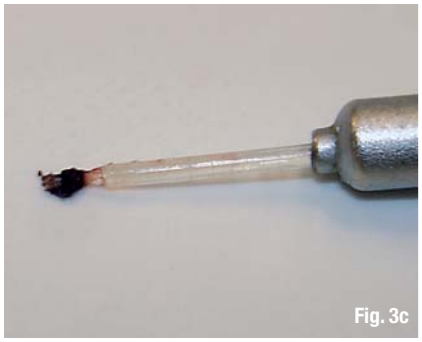

Fig. 3c


Fig. 3d

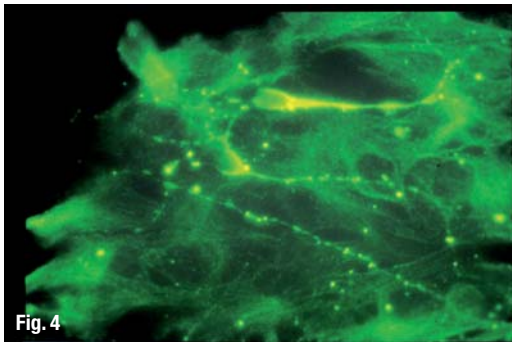


Fig. 4_Varicosity formation in the axons. (Courtesy of Ambrose Chan, Australia)

erable collateral damage to other microbes. Therefore, it appears that the Nd:YAG laser has a promising potential in eliminating the majority of the microbes in the pocket's soft tissue.

_The use of water-cooling

Negative thermal effects of the Nd:YAG laser have been reported in *in vitro* studies (Liu *et al.* 1999; Israel *et al.* 1997). However, *in vivo* effects on the root surface and the pulp are not well documented (Gaspirc & Skaleric 2001; Schwarz *et al.* 2008). The effect of laser irradiation on the surrounding tissues is influenced by parameters such as power, pulse, fibre size, fibre angulations and cooling/no cooling. White *et al.* (1994) suggest that powers between 0.3 and 3.0 W should not cause a damaging rise in intrapulpal temperature. Likewise, Gold and Vilardi (1994) and Spencer *et al.* (1996) also report that the use of laser at 4 W is safe and does not damage the root surface. The use of water-cooling is not standard in dentistry. In our experience, the cooling further reduces the risk of local carbonisation with the following increased absorption and unwanted tissue destruction. In spite of the use of 3 W in our studies, the speed of operation was still satisfactory and no carbonisation was observed. The advantage of using water is also relevant as described above for the accumulation of carbonised tissue on the probe, as described below.

It is essential to understand that the effect of the Nd:YAG is not based upon heating, but upon selective absorption in the tissue. Electrocautery, on the other hand, causes uncontrolled tissue necrosis and non-selective effects on microbes. Adding water-cooling to the electrocauter is not standard procedure, but by doing so, the cutting effect is slower but carbonisation is reduced and post-operative healing is improved.

_Dental calculus

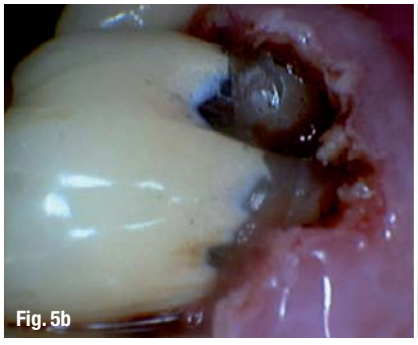
It has been postulated that the use of Nd:YAG laser prior to SRP softens the calculus deposits and makes conventional SRP easier. However, the marginal benefit of this procedure probably does not compensate for the potential damage to the root surface. On the other hand, the use of the Nd:YAG laser can be compared to open flap surgery. By removing the epithelial lining and widening the access to the root surface, calculus deposits are made visible and can therefore be removed conventionally with greater accuracy. The photographs above illustrate this possibility (Figs. 1a & d). The advantage of this technique is obvious, since there is no need for anaesthesia other than topical anaesthesia occasionally, there is no bleeding, and no need for sutures or re-appointment to remove the sutures. In addition, there is less post-operative pain and oedema. The laser irradiation itself creates an anaesthetic period of up to 24 hours, after which the patient experiences some tenderness in the area. In short, this is a cost-effective procedure with benefits for the operator and the patient.

_The technique

Several techniques have been proposed. In our own studies (Qadri *et al.* 2008, 2010), a 600 µm fibre was used in contact with the soft tissue only, in constant motion and with water-cooling. To be able to compare the effect with SRP, both sides of the mouth were treated by SRP before the Nd:YAG was used as an adjunct treatment. Clinically, we prefer a different approach. The pocket epithelial lining is first removed with the fibre at an angle of approximately 30°, avoiding contact with the root. This approach creates a funnel-like shape of the pocket with a reduction of the pocket depth by a few mil-

Fig. 5a_Example of the use of Nd:YAG tissue ablation using only Xylocaine ointment immediately before treatment.
Fig. 5b_The post-op situation.
Fig. 5c_One week post-op.







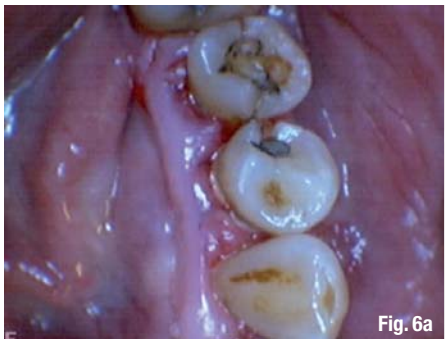

Fig. 6a


Fig. 6b

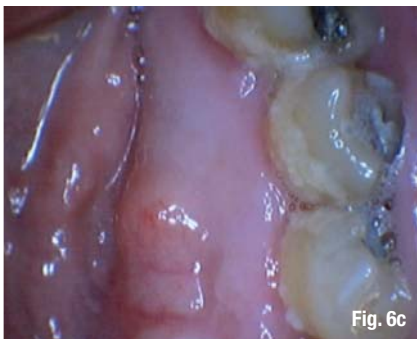

Fig. 6c

Fig. 6a–c_Nd:YAG treatment without anaesthesia (day of treatment, at seven weeks and at three months). Note the good condition of the gingiva at three months in spite of poor oral hygiene.

limetres. Once this has been done, the pocket is open for inspection, with no or little bleeding, and SRP can be performed with excellent visual control.

_The characteristics of different Nd:YAG fibres

Most bare fibres consist of a glass rod core made of silica quartz with an outer surface cladding that has a different refractive index from that of the silica-quartz fibre, and an outer protective vinyl jacket. The standard options are diameters ranging from 200 to 600 µm. As the fibre diameter decreases, the energy densities increase and fibre flexibility increases. Thin fibres are popular for non-contact irradiation because of the high power density but less than ideal for closed curettage, because they are too prone to fracture and the energy density is too high. The energy density of a 300 µm fibre is four times as high as that of a 600 µm fibre. Thus, the use of a thin fibre in a closed area has disadvantages. The high power densities will easily cause charred areas in the pocket and sticking of carbonised tissue to the tip. In the dark carbonised areas, absorption of the light increases, and so does heat. The aim of the laser treatment is not to use the instrument as a thermocauter but to take advantage of the interaction between the light and the specific tissue targeted. Further to that, a thicker diameter makes the fibre stronger and difficult-to-reach areas can more comfortably be accessed.

Figure 2 shows the distribution of the light at the fibre tip. As can be seen, the light is not only distributed along the axis of the fibre, but also to a considerable degree to the lateral sides. This is illustrated by the plume of smoke caused by the lateral spread of the beam and only occurring in pigmented (dark) structures.

During treatment, the fibre has to be cleaned and cut frequently. The output at the tip can be reduced by more than 50 % after being used around a single tooth. By using water-cooling, there will be less carbonised tissue in the pocket epithelium and less on the fibre as well. The debris sticking to the fibre will also be easier to remove (Figs. 3a & b). Further to that, the fibre should be kept in constant motion during therapy. The cutting capacity of the fibre is greater when in motion than in a stationary position.

Nd:YAG, which has little absorption in water, may be effectively cooled with simultaneous air and water spray. Several studies have confirmed that application of an air and water spray provides adequate heat protection of the pulp, comparable with cooling of the conventional rotary bur (Miserendino *et al.* 1994).

_Nd:YAG laser and pain perception

A major advantage of Nd:YAG laser periodontal therapy is that the procedure is more or less pain free. From the patient's point of view, this is certainly the major aspect. The degree of pain is largely related to the skill of the operator. Still, an anaesthetic gel is required in some cases during the initial phase of the surgery. After a while, it seems that the laser in itself provides an anaesthetic effect. The prolonged anaesthetic effect and the reduced trauma make compliance with post-operative home care easier.

When performing sulcular debridement with the laser around hypersensitive teeth, there is sometimes a pain reaction. In these cases, the tooth crown can be irradiated from a short distance without water until the pulp has been anaesthetised. For the same obvious reason, no water should be used when conventional hypersensitive tooth necks are treated with Nd:YAG laser. In combination with water, the area will be cleaned and the tubules will be even more open. Without water, they may be sealed.

The anaesthetic effect of the Nd:YAG laser is not fully understood, but in vitro studies have shown that Nd:YAG and 808 nm therapeutic lasers give rise to transient nodules along the axons, possibly slowing down nerve conduction. Figure 4 shows these varicosities after Nd:YAG irradiation of axons *in vitro*.

In general, it can be stated that the lasers themselves are not dangerous or damaging. It is the lack



Fig. 7a_Furcation one day of treatment.
Fig. 7b_Furcation at two years.
Fig. 8a_Mesial pocket before therapy.
Fig. 8b_Mesial pocket at one year.

of knowledge that results in damage. The undesirable side effects can vary firstly with power and energy density and secondly with the type of laser used.

In summary, the advantages of the Nd:YAG laser in periodontal therapy are:

1. reduced need for local anaesthesia;
2. reduced bleeding and better visual control of the pocket;
3. local reduction of microbes in the pocket;
4. reduction of post-operative discomfort; and
5. reduction of the need for pharmaceuticals.

_Nd:YAG and bone regeneration

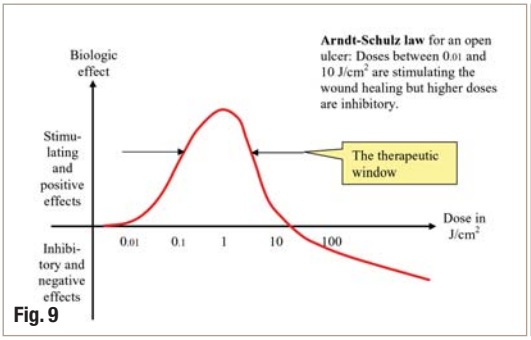
In our long-term study (Qadri 2010), some new bone was gained. In many clinical cases, much more bone regeneration has been seen, but typically in these cases the condition has been worse than the 4+ mm pockets treated in our study. Another difference in the more successful cases is that there were several therapy sessions, while the two Nd:YAG studies that are the subject of the present article only used one single irradiation. One single session may therefore not be optimal, even though it may be quite useful. Figures 7 & 8 show some examples of bone regeneration using the Nd:YAG laser.

_The therapeutic laser connection—Low-level laser therapy

While dental lasers such as the Nd:YAG and the Er:YAG are used for removal of tissue, the therapeutic lasers (also called low-level lasers and the therapy itself low-level laser therapy—LLLT) are non-thermal and cause cellular modifications through absorption in specific cellular photoreceptors, such as the cytochrome c oxidase, the terminal enzyme in the mitochondrial respiratory system. Such absorption causes a cascade of primary and secondary effects on conditions such as wound healing, oedema, inflammation, cellular proliferation and pain.

The first commercially available therapeutic laser was a helium-neon (HeNe) laser of 1 mW. The wavelength is 632.8 nm. This is a gas laser and it is rather large and fragile, and the light is distributed through a fragile optical fibre. The narrow bandwidth of this laser is believed to be an advantage, since the length of coherence increases with the narrowness of the wavelength. HeNe lasers are today not very common on the market. In the late 1990s, they were being replaced by diode lasers. This technology allowed for smaller machines and gradually also higher power. The gallium-arsenide laser has a wavelength of 904 nm and is a pulsed laser with a high peak power but an average power between 10 and 100 mW. The gallium-aluminium-arsenide laser has a wavelength of between 780 and 980 nm. Since the electrical driving system is less complicated, these lasers can be small and still offer high outputs, typically between 5 and 500 mW. Recently, HeNe lasers have begun to be replaced by semiconductor lasers containing indium gallium aluminium phosphate. Wavelengths are typically between 630 and 680 nm in the red part of the spectrum. Unlike the HeNe laser, these lasers can be small and handy and are typically in the 10 to 300 mW range.

LLLT follows the Arndt–Schultz law, which stipulates that for every substance, small doses stimulate, moderate doses inhibit, large doses kill. Here, the "killers" are the surgical lasers. There are specific dose



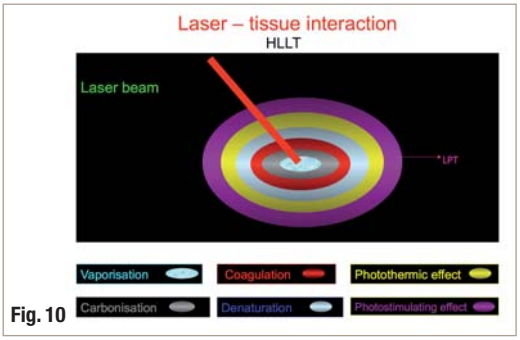


Fig. 9_The Arndt-Schultz law (Tunér & Hode 2004).
Fig. 10_Schematic illustration of the different light intensity zones. LPT is other term for LLLT. (Courtesy of Edson Nagib, Brazil)

intervals in LLLT: wound healing requires a low dose, anti-inflammatory effects 50 to 100 % higher and pain-relieving effects much higher, because here an inhibition is needed. But it should be born in mind that a medium dosage aimed at the inflammatory process is also pain relieving but not immediate. A high dose will inhibit pain but will also prolong the inflammatory phase, which in itself is painful (Tunér & Hode 1998; Huang *et al.* 2009). LLLT is probably most efficient during the first week following surgery (Gerbi *et al.* 2005; Fig. 9).

_Additional bio-stimulatory effect

Bio-stimulatory effects have been confirmed using the Nd:YAG and the Er:YAG at low fluences. Thus, the Nd:YAG laser has a certain bio-stimulatory effect and this contributes to enhanced post-operative healing (Abergel *et al.* 1984; Herman & Khosla 1989; Fortuna *et al.* 2002; Vescovi *et al.* 2008). The energy densities in the most peripheral zone fall within the bio-stimulatory range, as illustrated in Figure 10. The clinical effects in periodontal therapy are described by Qadri *et al.* (2005, 2007). The current literature on the use of LLLT in periodontal therapy has been reviewed by Eduardo *et al.* (2010).

_Summary

The different parameters and techniques used in Nd:YAG periodontal work contribute to the lack of a firm evidence-based conclusion regarding the usefulness of this therapeutic modality. This article summarises our own experiences. The use of water-cooling can, in our opinion, offer several advantages. The size and colour of the fibre also affect the outcome. Further clinical studies are needed to determine the optimal parameters for each indication._

_contact laser

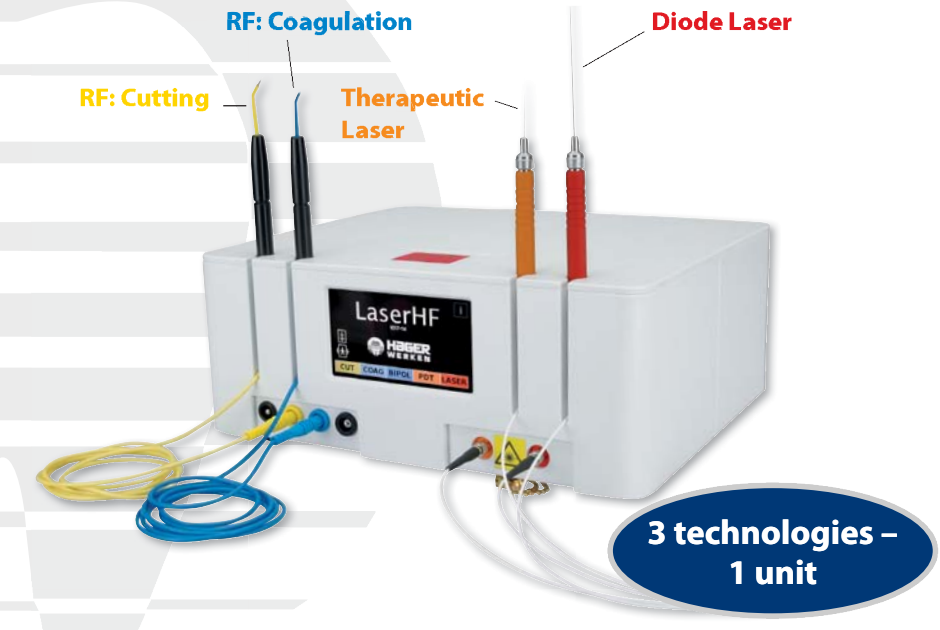
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