

Photoacoustic cavitation effects in oral surgery

How to preserve tissue and promote healing

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Introduction

The solid-state lasers used in dentistry were invented almost 30 years ago and they were initially aimed at creating new possibilities for the treatment of both hard and soft tissue with less tissue loss and mechanical or acoustic stress. Erbium lasers showed the highest potential for gentle but effective all-tissue treatment,¹ owing to their high absorption in water and hydroxyapatite. With technical improvements and power setting updates, Er:YAG and Er:YSGG also became popular for oral surgery and periodontics. Mid-infrared lasers are able to treat inflamed soft tissue, clean the root surfaces and cut the bone, subsequently stimulating bone regrowth.²⁻⁴ Another benefit is simultaneous decontamination due to release of oxygen radicals and local high temperature peaks. With especially designed tips, bone cutting and contouring are possible in non-contact mode, thus eliminating vibration stress, which is important in procedures like sinus lift or peri-implantitis flapped surgery. The next level in surgery that employs erbium laser fluence is 3D cleaning, generated by photoacoustic waves in fluids. The cavitation effect is caused by activating the water molecules with subablative energy levels of radia-

tion. This kind of interaction allows cleaning and decontamination of bone walls that are difficult to reach, as well as implant and root surfaces, at the same time, without risk of damaging them.

The physical phenomenon of cavitation is observed on surfaces in contact with non-stationary water content, while in experimental environment first is induced with ultrasonic activation. A series of explosions and implosions of formed bubbles towards the surface cause fast movement of the vapour and liquid and subsequent changes at the contact points. Thus, activated by subablative levels of Er:YAG (Er:YSGG) energy, water-based solutions can be used as a mediator to clean hard and soft tissue and implants of debris, granulations, biofilm and other loosely adhered substances. In laser dentistry, cavitation was first introduced as a method for irrigation of and debris removal from the root canal system. While some clinicians use high energies with specially designed tips in the canals with moderate thermal effects,^{5,6} others limit the action to the pulp chamber with low energies, reaching all parts of the endodontic system only through activation of the solution, caused by the photoacoustic effect of the Er:YAG laser.⁷

From a surgical stance, erbium laser cavitation is revolutionary, as this physical phenomenon allows the clinician to reach zones and structures in surgical sites that are otherwise unreachable using different means. Areas like the bone around the implant thread or behind the root apex, or undercuts in cysts or granulomas, and the deepest parts of periodontal pockets are impossible to treat directly without sacrificing large quantities of healthy bone, or damaging the roots or implant surface. Hence, when we add photoacoustic liquid activation to our surgical protocol in cleaning the inner part of periodontal or bone defects, in peri-implantitis treatment or in apicectomy, we can minimise the extent of intervention with the same cleaning and disinfection effect. Usually, cavitation is performed as part of flapped surgery, but in some periodontal cases, it is possible to employ it in a closed manner with activation of specific solutions, such as metronidazole or saline.

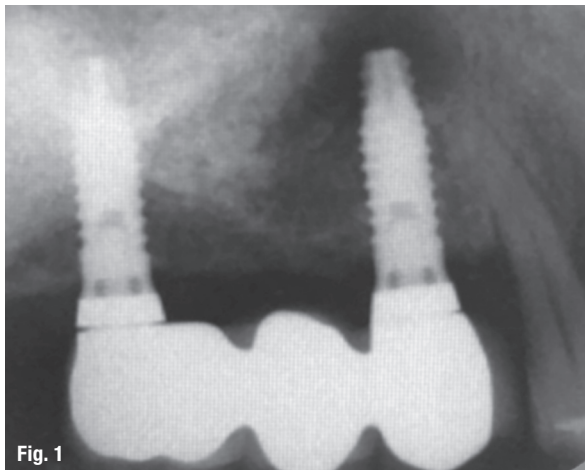


Fig. 1: Pre-op radiograph: despite the large area of osteolysis, the implants did not show any signs of inflammation. Tooth #24 was vital.



Fig. 2: Upon uncovering the bone lesion, non-resorbed, unintegrated parts of bovine bone were observed. **Fig. 3:** Using sufficient water spray when working with high energies is quick and safe and helps granulation tissue to flow out. **Fig. 4:** It is important to stop the laser, water and air and activate just the saline, injected into the defect. **Figs. 5 & 6:** Cavitation cleaning effect.

Materials and methods

In the cases described in this article, the Er:YAG lasers LightWalker AT (Fotona) and LiteTouch (Light Instruments) were used. The only common denominator of these dental laser systems is the wavelength, which is 2,940nm. Fotona uses an articulated arm with a mirror system for the energy delivery with a Gaussian beam profile. The LiteTouch system features Laser-in-Handpiece technology with a minimal energy transfer path and flat-hat beam profile. This profile enables very smooth and gentle interaction with soft and hard tissue, resulting in no ruptures or loose micro-parts, which is of great benefit for cutting soft tissue (with a special scalpel tip) or bone shaping, as it produces less swelling and promotes good healing. A Gaussian profile creates a peak of energy in the centre of the treated tissue spot, leading to micro-disruptions and -cracks at high energies. However, this method is much more effective when large volumes of tissue are to be removed without thermal effects. To avoid tissue stress, energy levels have to be reduced when approaching healthy tissue.

The LightWalker system includes six different pulse length settings (including QSP mode, a secondary sequenced pulse mode with a high hertz rate). Also, there is

the option of choosing very low energy levels, like 25 mJ and 50 Hz in SSP mode (50 μs). With LiteTouch, one can choose between soft- and hard-tissue mode. For these, there are fewer options for parameter settings. However, there are energy levels well linked with repetition rate, and these can be quickly set and changed during surgery. For surgical cavitation procedures, both companies offer conical tips with a 0.8mm aperture, which is ideal for treating large volumes of liquids, for which more energy is required. For closed periodontal pocket decontamination and cleaning, a 0.6mm fibre should be used with power of less than 1 W.

The patients who underwent the procedures described in this article were informed about the specific characteristics of the Er:YAG laser. They were also given a demonstration of the laser effect on an implant sample, comparing this treatment to a classical surgical approach. After forming their decision, informed consent forms were signed.

Case 1: Apical peri-implantitis

A male patient presented to the practice who had had multiple teeth extracted and undergone augmentation with bovine bone owing to severe periodontitis 1.5 years

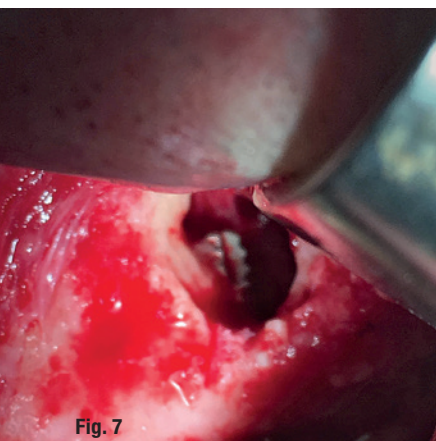


Fig. 7

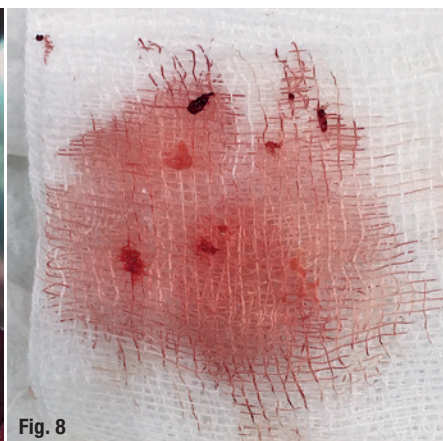


Fig. 8

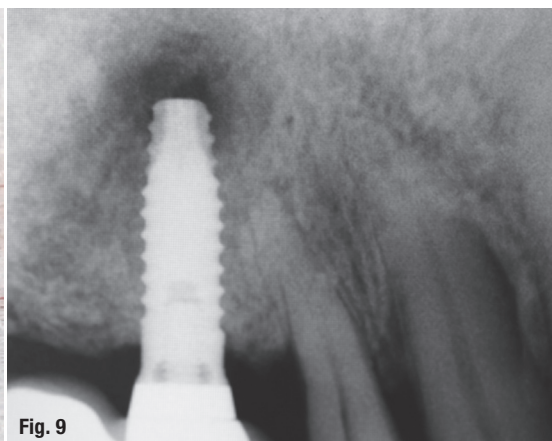


Fig. 9

Fig. 7: Clean and non-damaged implant. **Fig. 8:** Granulation tissue collected. **Fig. 9:** Almost total bone regrowth after four months. The neighbouring teeth were not affected.

prior to his visit to the practice. Preoperative radiographs were taken, and these showed that the bone structure was homogenous. The graft also appeared to be integrated and thus the decision for an implantation was made. Four Z1-Connect tissue-level implants (TBR) were placed on both sides of the posterior upper jaw, and after five months, they were functionally loaded with three-unit porcelain-fused-to-metal bridges. Three months later, the patient reported pain while eating, especially in the zone over the implant in position #25. Upon radiographic examination, granuloma-like osteolysis was detected around the apex of the implant (Fig. 1). A full-thickness flap was raised and the bone lesion was accessed by means of an Er:YAG laser (LightWalker) with a 1.2mm cylindrical tip and set to MSP mode (120µs), 20Hz/250mJ, water 5 and air 3 (Fig. 2). The internal surface of the flap was degranulated in LP mode (300µs) with parameters set at 20Hz/200mJ, water 5 and air 4, prior to bone preparation. After the defect exposure, the accessible inner walls were cleaned using the same tip, again in

MSP mode, but this time set at 15Hz/250mJ. The lower frequency helps to avoid possible thermal effects due to heat accumulation (Fig. 3).

Performing an apicotomy of an implant is not possible with a standard surgical protocol, considering the possible cutting of the implant apex with burs. The exposed titanium surface was cleaned with safe settings (SSP mode [50–60µs], 40Hz/50mJ, air 3 and water 5); however, the rear part of the implant and the back walls of the bone defect are unreachable this way. A hydro shock-activated saline solution effectively removed the debris and inflamed soft tissue through the cavitation effect in a closed space (Fig. 4). Ten to 15 cycles of cavitation with saline injection and subsequent activation were sufficient to clean all the hidden surfaces in this complex surgical wound (Figs. 5 & 6). It can be assumed that the wound is clean once there is no longer any granulation tissue coming out, nor massive bleeding, just clean blood that accumulates and forms a clot (Figs. 7 & 8). On a control radiograph

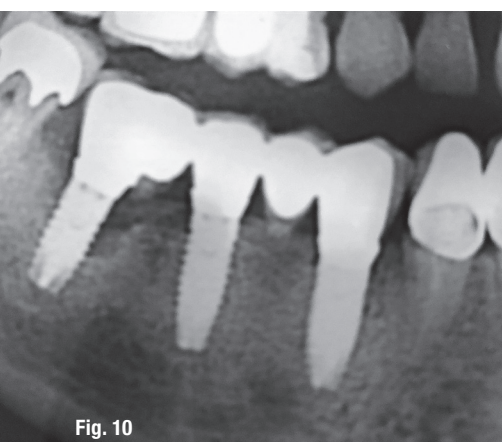


Fig. 10

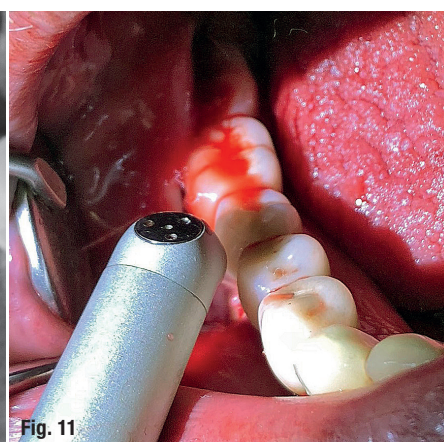


Fig. 11

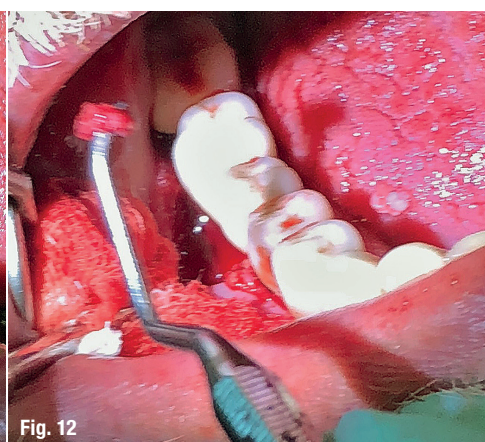


Fig. 12

Fig. 10: Initial signs of peri-implant inflammation also notable around implant #44. **Fig. 11:** With a repetition rate of over 30Hz, LiteTouch shows a cutting efficiency similar to that of near-infrared diode lasers, but without blood supply dependence. **Fig. 12:** The defect was wide enough to clean the inflamed tissue with a surgical curette.

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taken four months after the surgery, it could be seen that new bone had formed around the implant (Fig. 9).

Case 2: Severe marginal peri-implantitis

A 63-year-old patient complained about swelling and pus secretion from the gingivae near a bridge on three implants. Upon examination, marginal peri-implantitis was detected in the region of positions #45–47, and there was pus flowing out of the 7–8mm pockets around the implants. Also, bleeding on probing was present around all implants in this area. A radiograph revealed bone resorption mainly around position #47, which corresponded with the finding of the intra-oral examination (Fig. 10). For this case, a new model of the LiteTouch Er:YAG laser was used. The incision was made with a scalpel tip at 40Hz/100mJ in soft-tissue mode (Fig. 11). This mode allowed a quick and smooth cut, without contacting the bone. An excellent healing line could be seen after eight days. If one wants to cut with the laser in a flapped surgery, de-epithelialisation must be ensured prior to raising the flap. After preparation of the vestibular part, the inner surface of the flap was degranulated at 20Hz/200mJ in soft-tissue mode. Alternatively, this can be done closer to the bone at 20Hz/100mJ in hard-

tissue mode. The large volumes of granulation tissue that could be reached around the implants were removed manually (Fig. 12).

In the next phase, the rest of the inflamed tissue was removed using a hard-tissue pulse length at 15–20Hz/250mJ with a water and air spray and conical or chisel tips (Fig. 13). The amount of bleeding was tolerable and clean bone edges were present; thus, the procedure commenced with cavitation-based cleaning of the visible and unreachable zones (Fig. 14). For cavitation, saline should be forced into the bone chamber around the implant. Overflow serves as a shield against splattering blood and solution and lends effective fluence to the liquid (Fig. 15). In hard-tissue mode, 40Hz/50mJ and spray off, photoacoustic activation was performed more than 15 times until no more granulation tissue came out and a clean clot started to form (Figs. 16 & 17). In a final step, an allograft was used to fill the bone defect (Fig. 18). The bridge was not fixed right after the surgery, but after the stitches had been removed (Figs. 19 & 20). On a control radiograph taken after four months, it could be seen that new bone had formed and there were no clinical signs of infection or alteration of the surrounding tissue (Figs. 21 & 22).

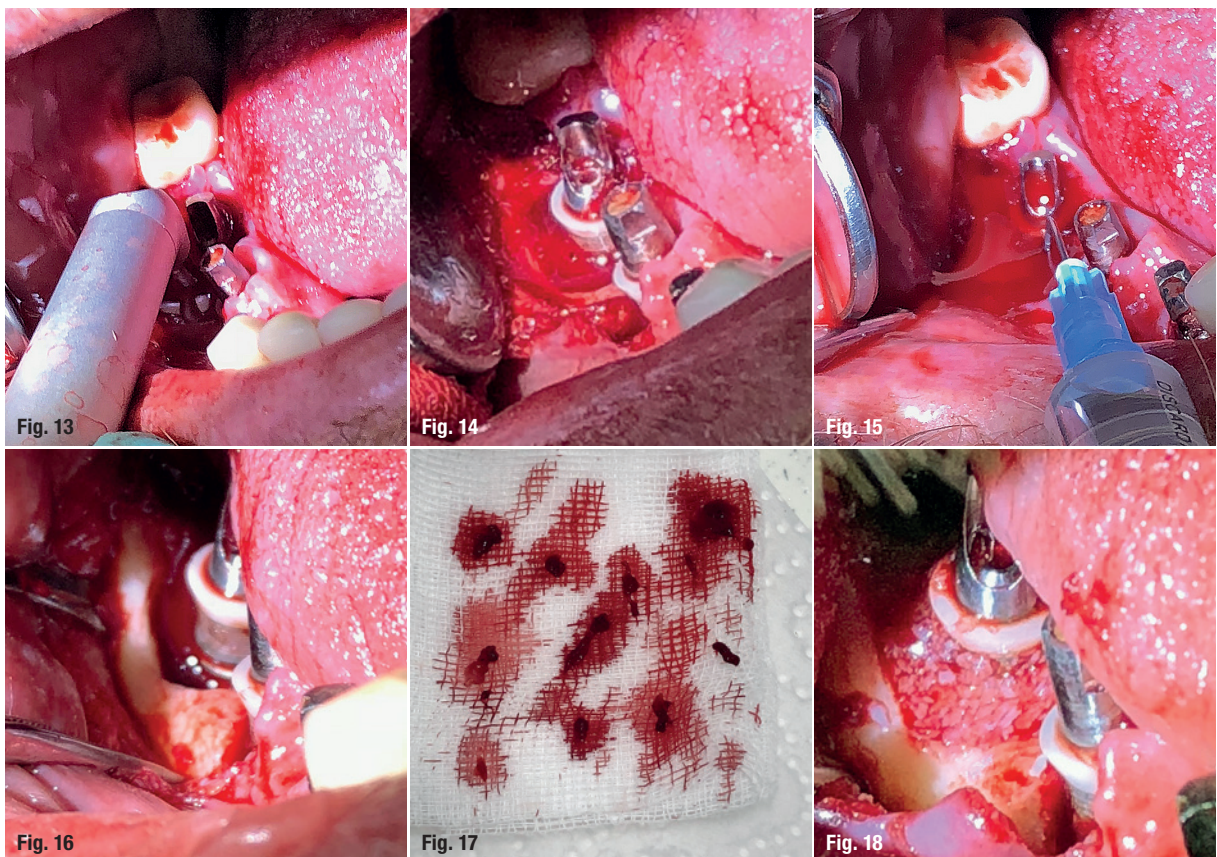
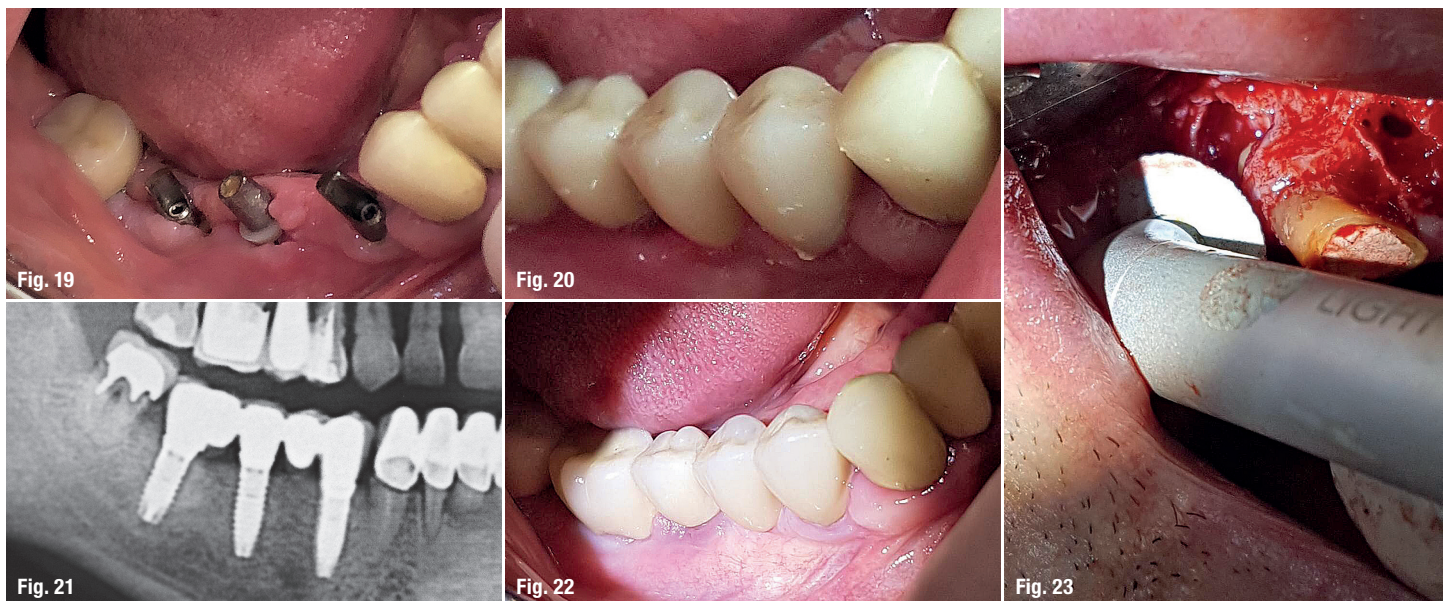


Fig. 13: Removal of the bridge ensured direct access to all areas of the bone wound. **Fig. 14:** Adequate clot formation is demonstration of well-cleaned bone and soft tissue. **Fig. 15:** Two implants were treated simultaneously. **Figs. 16 & 17:** The implant surface was clean, bleeding was negligible and a clot was forming. A great deal of granulation tissue was evacuated just by cavitation. **Fig. 18:** Human bone from a tissue bank was used for grafting.



Figs. 19 & 20: Almost no visible cutting line after eight days. The bridge was fixed with temporary cement. **Figs. 21 & 22:** Radiographic and clinical appearance after four months. **Fig. 23:** Rubber shield used to prevent saline solution spraying out.

Conclusion

To finalise this short demonstration of the power of the subablative energy of the Er:YAG laser, well mediated by liquids, is a discussion of the benefits of this technique. First, there is no direct contact and no risk of thermal damage or vibration stress. Owing to low energy levels, there are no loud sound effects compared with standard intervention in bone, making patients calmer and more relaxed. In addition, structures can be treated that are otherwise almost unreachable with tips for direct intervention, plus the chemical effects of cleaning solutions are used. Apart from that, it is a minimally invasive tissue-saving procedure that is much easier to carry out for general practitioners than a classical surgical approach. Lastly, there is no risk of maxillary sinus membrane rupture during treatment in proximity.

However, there are also downsides to this procedure: fast evacuation of the liquid in cases of shallow defects, for which there are some solutions at present (Fig. 23). According to clinical experience, the repetition rate is more important than the energy level for the fast activation and overflow of the mediator. For defects that are difficult to reach, a hertz rate of between 20 and 30 at 40mJ is recommended. Cavitation treatment can be added to every surgical protocol in bone and soft tissue, owing to its simplicity and no additional preparation requirements—even at the end of any procedure—instead of standard saline rinsing. Further upgrades to this technique in oral surgery are to be expected from engineers and dental

laser manufacturers in the future, meeting the complex needs for effectively treating different and unpredictable shapes and volumes.

about the author



Dr Evgeniy Mironov is a dentist and internationally published author from Bulgaria. He graduated in dentistry from the Medical University–Sofia in Bulgaria in 2002. Since 2003, he has been practising general dentistry in his own private practice and has a special interest in aesthetic dentistry, implantology and oral surgery. In 2013, he completed the Master of Science in Lasers in Dentistry programme at RWTH Aachen University in Germany. He lectures annually at the International Laser Dental Academy in Plovdiv in Bulgaria, and Deutsche Gesellschaft für Laserzahnheilkunde (German association for laser dentistry) and International Society for Laser Dentistry congresses, and at events hosted by dental laser manufacturers in Bulgaria and Slovenia. He is a member of the International Society for Laser Dentistry.

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