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CASE REPORT: Specific Oral Bone Surgery Procedures Requiring the Use of Er:YAG Laser in QSP Mode for Optimal Performance

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ABSTRACT

This case report presents modern alternatives to classical oral-surgery procedures with the use of Erbium lasers, which allow a shorter recovery period, no recurrence and no need for antibiotic protection.

A minimally invasive approach provides more predictable results in different age groups of patients, minimizing the importance of the general condition of the patient on the success of the operation.

Methods for bone augmentation and bone sculpture, with a corresponding dosage of laser energy are shown, regulating the residual low energy as needed for indirect stimulation (or non-stimulation) of the neighboring tissues. For example, upon removal of the exostoses, it is not desirable to use too high power due to saturation of the target and the influence on the underlying tissues, with the consequent risk of stimulation of new exostoses. And opposite to this - on procedures for bone augmentation, additional stimulation is desired with a view to obtaining a larger volume of bone tissue. QSP mode allows the operator to have a fine-tuned dosage according to the specific goals of each procedure.

Key words: QSP, bone surgery, implant.

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I. INTRODUCTION

This article is not only a presentation of clinical cases, but a guide to modern oral bone surgery based on concrete clinical goals. Alternatives to classical oral surgery procedures are well-known and have been widely used in the past 20 years. Lasers of different wavelength, ultrasonic surgical tools and other innovations have come to replace rotating instruments for bone resections and remodeling. Benefits like shorter recovery periods, no need for antibiotic protection, and reduced swelling and postoperative pain are well described in the literature. Minimally invasive approaches provide predictable results in different age groups of patients, minimizing dependence on the general condition of the patient for the success of the operation.

Today, using the latest capabilities to adjust settings with QSP mode, we can control and predict the bone's reaction to a treatment. Working close to soft-tissue mode settings, allowing the desired quantity of heat to penetrate into the underlying layers without causing necrosis or stimulation, ensures that the bone surface will heal well and remain in the same shape and volume. The opposite situation occurs when bone is treated with moderate energy levels and with no heat penetration into deeper layers due to cold ablation, but with rising mechanisms of bio-stimulation and collagen-producing cell proliferation.

Based on the considerations above, methods for bone augmentation and bone sculpture – with a corresponding dosage of laser energy – can be used, regulating the residual low energy as needed for indirect stimulation (or non-stimulation) of the neighboring tissues. For example, upon removal of the exostoses, care must be taken to not use excessively high power due to the saturation of the target and the influence on the underlying tissues, with a consequent risk of stimulation of new exostoses. And opposite to this – on procedures for bone augmentation, additional stimulation is desired with a view to obtaining a larger volume of bone tissue. QSP mode allows the operator to achieve a fine-tuned dosage according to the specific goals of each procedure.

II. MATERIALS AND METHODS

In search of safe and effective energy levels for bone modelling, many authors have tested and described different Erbium lasers settings, excluding those with significant thermal effects (mainly those with relatively long pulse durations and fiber delivery systems)[1,2]. Frequently claimed as being less effective and yielding irregular reparative bone formation, Er:YAG has been described in these articles as unsuitable for replacing the classical saw and bur bone resection techniques [1,2]. However, after years of dental-laser developments and improvements, many scientists have reported successful bone ablation without thermal damage, and with a normal recovery process [3,4]. In 2004 Pourzarandian et al. reported that the Er:YAG laser even promotes the healing process with histologically proven stimulation of reparative fibroblast cells and greater re-vascularization compared to the CO_2 laser and bur [5].

For certain clinical reasons, it is acceptable and even desirable to treat bone tissue with residual thermal fluence, mainly in cases of bone modelling, where recurrence of uncontrolled growth is to be avoided. Exostosis removal is a typical example for this group of Er:YAG laser bone applications.

Contrary to this, in zones of insufficient bone volume, additional stimulation of the cortical bone is a goal, together with autogenous or synthetic grafting material placement. In this procedure, the main effect of laser cortical bone surface conditioning is for preparation of the treated area for graft reception and the inducement of bleeding for better attachment of the material to the recipient bone. When the right settings are used, all laser energy is used for controlled cold ablation in the superficial layers without thermal effects to the neighboring tissues, but with low-level, non-thermal energy deposited in the underlying bone. The indirect effects of the Erbium laser irradiation is known as collagen stimulation and osteoblast cell proliferation [6].

According to this, we can say that even the negative and unwanted (at a first glance) thermal effects can be used in a positive way to achieve specific goals, and on the other hand – the invisible and underestimated low-level effect can lead to a clinically noticeable gain in newly-formed bone growth.

Quantum Square Pulse (QSP) is an Er:YAG mode used in the Fotona LightWalker AT laser system, where higher repetition rates for the Erbium:YAG laser are possible due to "packing" four-to-five super-short pulses into one long pulse. A lot of benefits are achieved by this – avoiding the absorption of incoming energy in the debris cloud from the previous pulse [7], working faster compared to short pulse durations, with clean preparation borders and ready-to-bond hard dental tissues [8]. QSP mode allows the practitioner to select the system parameters in order to choose between a light thermal effect or low-level energy with no thermal behavior.

By reducing the energy level to slightly above the ablation threshold, we are not causing substrate heating, but full energy deposition in the target with no residual low energy penetrating deeper. At the same time, a high repetition rate of 20 Hz of Quantum Square Pulses is equal to almost 100 standard pulses, which leads to warming in the laser-tissue interaction zone, causing superficial necrosis, but not deeply enough to prolong the healing process. With these types of settings – for example 110-120 mJ/20 Hz QSP, we can avoid secondary stimulation of the irradiated bone and the recurrence of exostosis without influencing the normal recovery period.

With a pulse energy quite large to be sufficiently above the ablation threshold, the clinician can suppose that a stream of residual low energy will penetrate deeper, leading to indirect new bone formation on the cellular level. High energy allows for working faster with low repetition rates (150-200 mJ/10 Hz QSP), but also safer because of the cold ablation regime, for precisely preparing graft recipient areas.

III. CASES

a) Case 1: Trans-gingival flapless osteoplasty

A 60-year-old lady reported that soon after the extraction of tooth 16, bone growth from the wound margin had begun and pain occurred when touched by food or a tooth brush. After the intra-oral exam, exostosis was detected on the vestibular margin of the extraction site. A fast decision for removal of the extra bone was taken, and in the same visit the procedure was performed under local anesthesia.

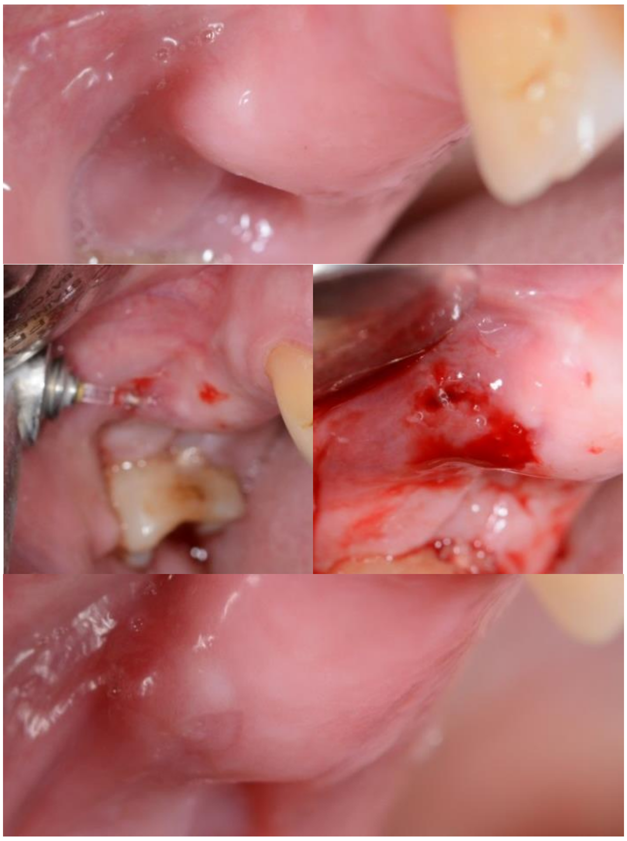

Fig. 1: Trans-gingival flapless osteoplasty case

b) Case 2: Sub-periosteal cortical stimulation with autogenous graft PRF

The next case demonstrates how we can achieve bone growth stimulation with the same mode of operation when additional volume formation is desirable. This surface treatment is especially apt before placement of bone augmentation material. The most common case for grafting is where crystal volume and quality is needed, but cortical bone without any preparation is not a good host because of the lack of retention and blood supply. Alteration of the surface can positively change this, and that's the goal of pre-treatment of the bone prior to graft placement. With their minimally invasive nature, shorter recovery period and earlier opportunity for using the newly formed bone, treatments with Erbium laser are the choice of many practitioners for this "boutique surgery".

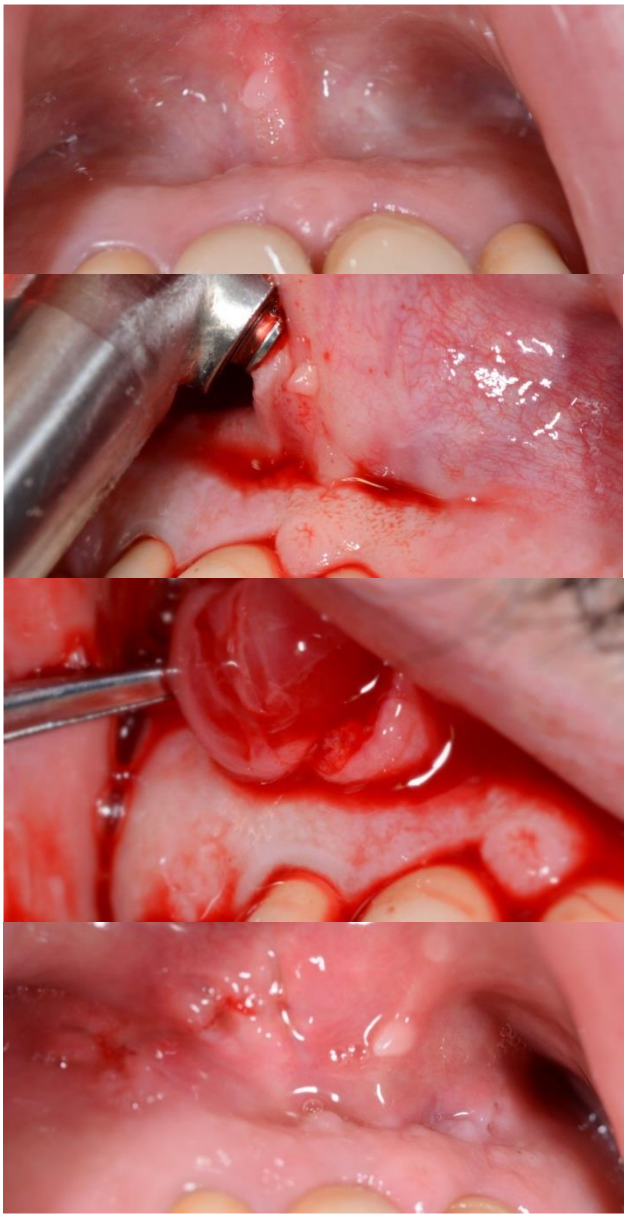

Fig. 2: Sub-periosteal cortical stimulation with autogenous graft PRF case

The patient in this case is a 50-year-old male with a Zirconia bridge to replace the missing central incisors on the upper jaw. He asked for implant options, and due to insufficient thickness of the maxilla in the region of interest, my advice was to start with a PRF graft, placed subperiosteally, for an implant preparation of the bone.

After local anesthesia and a minimal scalpel cut in full thickness, soft-tissue tunnel preparation was done and the PRF host space was accessible with a long sapphire chisel tip. Normal crestal bone has a compact layer that is hard and well calcified, so full preparation requires high energy and high peak power. In this case, we again used QSP mode, but at 12 Hz and 180 mJ of pulse energy, guaranteeing cold ablation and a residual low level of energy to pass below. This train of super-short pulses caused sufficient bleeding and no thermal effects. In 10 days, graft resorption was not observed, and the volume achieved was easy noticeable. The native bone type here was between II and III, so laser activation of cells and blood circulation also improved the bone quality in depth.

c) Immediate replacement of the non-integrated implant case

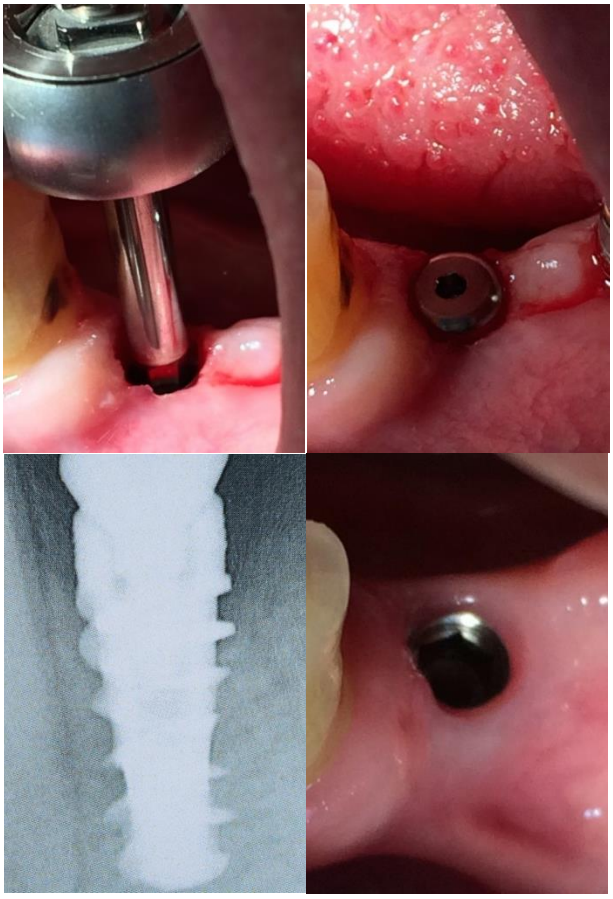

Fig. 3: Immediate replacement of the non-integrated implant case

Bone stimulation and disinfection was also the goal in this case, where a failed implant had to be replaced. A 65-year-old female showed symptoms of implant failure in the region of tooth 34. A decision for the immediate replacement with another type and model was taken. Under local anesthesia after initial de-epithelization of the surrounding gingiva with LP mode at 20 Hz/200 mJ, air-4/water-3, the old implant was unscrewed. Then, with the longest possible cylindrical sapphire tip, the entire length of the implant socket was treated in a circular manner from the crestal bone to the bottom and back with QSP mode at 12 Hz/180 mJ, air-3/water-4. After this procedure, with the drill calibrated at a 0.3 mm smaller diameter than the new implant, the new shape for implantation was done. Again in QSP mode, but with 10 Hz/150 mJ, the bone was conditioned prior to new implant fixation.

A healing abutment was placed instead of a standard covering screw. In two months the new implant showed excellent osseointegration and stability without any symptoms of inflammation.

The role of the laser in this case is important in every step of the implant replacement: creating a wide opening with de-epithelization and disinfection, cleaning the epithelium of the implant socket, and bone conditioning. The risk of epithelial invasion in the bone-implant interface is too high to try this procedure without a revolutionary tool like the Er:YAG laser, with its effects of cutting, drilling, sterilization and bone-cell stimulation.

IV. DISCUSSION

These three cases are a representative sample of smaller surgical procedures that can be performed with a very high success rate in the field of oral surgery and pathology. With the latest technological improvements of Erbium lasers, we can fine tune the parameters and even the unwanted effects like thermal emission can be used in our favor.

25 years ago, lasers with relatively long (for hard-tissue ablation) pulse durations (200 microseconds) were not seen as suitable for bone cutting and remodeling [1]. Technical limitations kept this taboo for a long time, and lasers were used mainly for soft-tissue management.

With the development of shorter pulse durations with high peak power and cold-ablation regimes, many authors proved that bone healing can even be promoted with Er:YAG laser irradiation [5,6].

Based on all the finding throughout the years, two main postulates remain in the field of Er:YAG bone surgery. First - working with a high Hertz rate and long pulse durations leads to overheating of the substrate and limited necrosis, with a prolonged healing period [1]. And second - short pulse durations and low repetition rates lead to negligible thermal effects with cold bone ablation and safe tissue removal with shorter recovery periods compared to standard drills and saws [3].

But what happens if we work in safe conditions, with relatively high peak power and a lot of energy deposited in the tissue? Even in the cold regime - additional stimulation of underlying bone structures occurs, causing osteoblast activation and new bone formation, which is in some cases an unwanted effect – like with exostosis removal. So we have to look back to the thermal effect and use it in a specific manner, very carefully and controllably to cause a limited sub-necrotic area and full energy depletion in the target.

Four years of clinical experience has suggested that way to do this is to use a mode in which pulse energy can be adjusted very precisely in small steps around the ablation threshold, and with the repetition rate we can cause a controlled thermal effect. Thanks to the QSP mode in Fotona's LightWalker, these parameters are under fine control; with a difference of only 20 mJ and 5 Hz, we can shift between stimulation or inhibition of bone growth. In vitro studies to confirm the effect of the 20 mJ and 5 Hz difference are in progress.

V. CONCLUSIONS

The category of minor bone surgery and implantology procedures is becoming more popular every year, and well-proven, safe settings for Erbium lasers are needed and critical for the success of these operations, especially for general practitioners, for whom this kind of surgery is often just a part of their normal everyday work and shouldn't be a big challenge.

Just few seconds of laser action can save the patient months of waiting for bone or implant healing, making it irreplaceable in many cases, where everything except the Erbium laser is a compromise.

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