Photodynamic therapy with the new active ingredient Perio Green

Author Dr Ralf Borchers, MSc, Bünde

Introduction

Indocyanine green combats pathogenic bacteria simply, effectively and without side effects.

Until now, systematic periodontal treatments have often required the additional use of systemic antibiotic medication as well as the normal manual treatment involving cleaning, curettage and after-care in order to eliminate treatment-resistant pathogens more effectively and to achieve a long-lasting therapeutic effect.

However, the administration of antibiotics is always associated with side effects which unfortunately cannot be avoided with classic therapy. In the following article, a case study will therefore be used to illustrate a new, gentle method of bacterial reduction in gingival pockets: minimally invasive photodynamic therapy (PDT) with indocyanine green (Perio Green, elexxion AG) which works without antibiotics and causes no systemic side effects or unsightly discolouration.

In periodontology, the laser is frequently used as adjuvant therapy because of its bactericidal mode of action. Various studies using laser light to decontaminate gingival pockets have delivered promising results. Diode lasers (810 to 980 nm) with output levels of 1 to 2 watts are mostly used for this purpose. Depending on the practitioner’s manual dexterity and experience, this laser adjuvant therapy can be performed without anaesthetic.

Pain-free periodontal therapy without cytotoxic effects

Photodynamic therapy is a new and promising approach to eliminating periodontal pathogens and bacteria. Unlike laser application on its own, a photodynamic active ingredient (photosensitiser) is absolutely essential to this technique. This dye adheres to matrix proteins in the bacterial membrane and, when exposed to laser light of the corresponding wavelength, reacts with the release of free oxygen radicals. This singlet oxygen alters the plasma proteins so that they are unable to continue metabolising and hence die.

Correct use of the defined laser light source in combination with the photosensitiser is essential in this process. This means that the dye must be specifically coordinated with the wavelength used. If not, no absorption of the laser light takes place in the active ingredient. The energy settings employed lie within milliwatt range (mainly 100 mW) so that pain-free treatment is possible for patients.

A systemic effect (as with antibiotic administration) can be prevented completely by choosing the right photodynamic sensitiser. As the photosensitiser only docks onto the bacterial membrane, no side effects such as cytotoxic effects occur in endogenous cells. In
addition, no heating of the tissue ensues and there is no evaporation of tissue or bacterial residues; anaesthesia is usually unnecessary.

 Green photosensitiser leaves no dye residues

While blue PDT dyes such as methylene or toluidine blue were mainly used until recently, green photosensitisers such as indocyanine green are now available. As the green dye is used with diode lasers with 810 nm wavelength, it is not necessary to purchase a special laser for PDT—compared with blue dyes this is an economic advantage to dental practices that should not be underestimated.

Indocyanine green is a “true” photosensitiser which only reacts when the appropriate laser light is supplied but otherwise displays no therapeutic effect—neither negative nor positive. By contrast, the blue PDT active ingredients have a bacteriostatic or bactericidal action even without the supply of light; strictly speaking, therefore, they are not true photosensitisers.

Another disadvantage of methylene and toluidine blue: particularly in the anterior area, they continuously cause prolonged blue discolouration of the tissue and/or teeth, which patients find extremely unsightly. Indocyanine green deals with this problem because the sensitiser as a unique laser-activatable ingredient has the property of coupling selectively to bacterial cells while at the same time it is far easier to rinse off with water than the “blue products” found on the market.

The indocyanine green that is used as the raw material for the new PerioGreen is identical to the dye that...
Photodynamic therapy

As the photosensitizer mixed into Perio Green is only effective for about two hours, the tablet was dissolved in sterile water only shortly before treatment was carried out. The resulting laser-activatable dye solution was drawn up into a disposable syringe (Fig. 3), then spread into the gingival pockets by a thin, blunt application tip. Owing to the low viscosity of the active ingredient, penetration down to the floor of the pocket is guaranteed. After two minutes’ exposure to the solution and subsequently rinsing of the mouth, pulsed light activation was performed with the elexxion laser. To do this, a laser fibre 200 to 300 µm in diameter was inserted into the pocket and the active ingredient was irradiated for 30 seconds (Fig. 4).

After-care

The patient came back a week later for recall when another Perio Green treatment was carried out. Microbiological testing to identify germs was repeated under the same conditions as the first test in order to monitor the success of the treatment. The results of the test (Fig. 5) suggest that the new active ingredient Perio Green in combination with the specific laser light of the elexxion laser is a suitable tool for effective elimination of micro-flora.

Conclusion

The photodynamic therapy with indocyanine green presented here is not only effective at combatting bacteria in the oral cavity, but it is also free of side effects, offers uncomplicated handling for practitioner and patient and involves minimal treatment time (approx. 45 minutes for a complete U4/L4 treatment). Other patient treatments performed in my practice as well as current clinical trials with Perio Green also confirm the success of this minimally invasive form of therapy. Thus the positive aspects of indocyanine green treatment were presented in detail by several speakers during the DGL (German Association for Laser Dentistry) and LEC congress (Laser Beginners Congress) held last year in early September in Leipzig, Germany.

Contact

Dr. Ralf Borchers, MSc
Master of Science in Lasers in Dentistry
European Master of Oral Laser Application
Bahnhofstraße 14, 32257 Bünde, Germany
Tel.: +49 5223 10222
Dr.Borchers@praxis-borchers.de
www.praxis-borchers.de
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 Majesty Sheikh Hamdan Bin Rashid Al Maktoum
Deputy Ruler of Dubai, Minister of Finance
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Er:YAG laser etching of hypoplastic enamel

Authors_Prof. Dr Georgi Tomov, Dr Ana Minovska, Birute Rakauskaite & Laura Navasaityte

**Introduction**

Enamel hypoplasia is the most common abnormality of development and mineralisation of human teeth. The lesion is characterised by a quantitative defect in enamel tissue resulting from an undetermined metabolic injury to the formative cells—the ameloblasts. Enamel hypoplasia is endemic in many countries of the world and is commonly reported in association with disease of childhood. The hypoplastic enamel has differences in structure and composition that may affect its etching patterns. Enamel etch by the acid can be additionally complicated by variability of penetration depth, and strong washing and drying affecting the bond strength. Er:YAG lasers are discussed as an alternative of acid etching, but there are no scientific evidences to support this hypothesis.
This in vitro study compares the etching effects of acid etchant and Er:YAG laser on hypoplastic enamel (HE) and normal enamel (NE) of extracted human teeth.

Material and methods

Teeth extracted due to advanced periodontal diseases were collected by patients. All the HE patients had been previously diagnosed by G. Tomov and G. Nikolova using clinical and radiographic criteria. Clinically, all HE teeth have showed many round, pin head-sized pits, which were concentrated mainly on the buccal and lingual surfaces. The teeth had been kept in saline until the time of study. The buccal surface of each tooth (10 HE and 10 NE, all frontal teeth) was divided and the right side was treated with 37% phosphoric acid for 60 sec. while the left side was irradiated by Er:YAG radiation (LiteTouch 200 mJ/35 Hz for 10 sec., Figs. 1a and b). The treated surfaces were evaluated using a scanning electron microscope (SEM), Phillips 505 scanning electron microscope (Phillips Electronic Eindhoven, Netherlands). For SEM analysis, the samples were fixed (2.5% glutaraldehyde, 12 h, 4°C), dehydrated (25–100% ethanol), dried, and sputter-coated with gold and examined under different magnifications. The observed changes were photographed and analysed.

Results

Normal enamel (NE) after acid etching

After treatment with 37% phosphoric acid for 60 sec., the etched area generally showed a type 1 pattern with the prism cores preferentially removed. However, in small, isolated areas, the etching pattern was similar to that of type 2, i.e., prism peripheries were preferentially removed (Fig. 2a). A type 3 etching pattern (general removal of tooth structure without exposing prism structure) was also observed in other isolated areas.

Hypoplastic enamel (HE) after acid etching

The acid-etched HE do not exhibit the typical etching pattern seen in control enamel. In the areas where intact surface enamel was presented (without pits), 37% phosphoric acid etching for 60 sec. leads to irregular and patchy loss of surface tooth structure without evidence of uniform etching patterns (Fig. 2b). After etching, no uniform removal of hypoplastic (and hypomineralised) enamel is evident.

Normal enamel (NE) and hypoplastic enamel (HE) after laser conditioning

A comparison of the laser-treated surfaces showed that laser radiation caused a uniform roughness of the enamel for both HE and NE teeth. The morphology patterns were similar without melted or damaged surfaces (Figs. 3a and b).
Please send me further information on the 43rd INTERNATIONAL ANNUAL CONGRESS OF THE DGZI on October 4–5, 2013, in Berlin, Germany.
The laser-treated surfaces showed that laser radiation caused a desired and uniform roughness of the enamel for both HE (a) and NE (b) teeth.

**Discussion**

As the failure rates of adhesive restorations in HE teeth may be high, the question often arises as to whether this type of dental enamel may be successfully etched. The present study addresses this important clinical issue in one clinical variant of Amelogenesis imperfecta, namely, pitted hypoplastic type, using extracted permanent teeth. The common features of normal enamel, as well as the abnormal HE, have been described in previous publications. However, there have been no previous studies comparing the effects of acid etching and Er:YAG laser conditioning on hypoplastic enamel. Our study shows that the three classical acid-etching patterns found in normal enamel cannot be reproduced in the HE type. In the case of the pitted hypoplastic variant, the etching pattern was similar to that of type 1, in which the prism cores were preferentially removed. The pattern of prism dissolution was irregular and did not appear to be related to prism structure. Additionally, it is also likely that, because of smaller or weaker prisms, the length of time of the acid etch or the concentration of etchant may not be optimal to produce the classical etch patterns. These hypotheses are based on findings of previous studies which found abnormalities of prism structure, as well as reduction in enamel thickness by more than half compared to normal enamel. The acid etching of a less organised hypoplastic enamel structure may result in a pattern that is not the classic etched pattern, which may have a detrimental effect on bonding between the adhesive materials and the affected enamel.

The Er:YAG laser etching seems to be an alternative approach for adhesive treatment of hypoplastic enamel defects. LiteTouch Er:YAG laser used in this study (Syneron, Israel) emits a beam with a 2,940 nm wavelength which is absorbed mostly by water. The mechanism of ablation is based on interaction between laser energy and hydroxyapatite incorporated water which results in microexplosions. It is believed that this process is the mechanism of ablating particles from dental tissues without overheating and without smear layer formation. The program “hard tissue mode” removes enamel, dentin and dental caries effectively and without visible carbonisation or disturbance of the dental microstructure. Evaluated under SEM, the dental tissues treated with LiteTouch Er:YAG laser showed rough and irregular surface without presence of smear layer. Treated enamel shows preserved prismatic structure, but also strong retentions. These results suggested Er:YAG lasers to be effective in the treatment of hypoplastic enamel in order to avoid acid etching. From a clinical point of view, the presence of typical and uniform morphological changes after Er:YAG laser treatment in both normal and hypoplastic enamel suggests that bonding of composite resins may be feasible in most patients with HE. However, the possible advantages of Er:YAG laser conditioning of HE needs further clinical investigation to be approved.

**Conclusions**

1. In the pitted hypoplastic type of EH, classical etching patterns after treatment with 37 % phosphoric acid like those seen in normal enamel, are generally not observed.
2. Er:YAG laser conditioning produces similar morphological changes in both normal and hypoplastic enamel.

Editorial note: A list of references is available from the publisher.

**Contact**

Prof. Dr Georgi Tomov  
DDS, MSc, PhD  
3 Hristo Botev Blvd., 4000 Plovdiv, Bulgaria  
Oral Pathology Department, Faculty of Dental Medicine, Medical University, Plovdiv  
Mobile: +359 896742065
SEM analysis of the laser activation of final irrigants for smear layer removal

Authors Dr Vivek Hegde, Dr Naresh Thukral, Dr Sucheta Sathe, Dr Shachi Goenka & Dr Paresh Jain, India

Introduction

The complete restoration of the root canal space with an inert filling material and the creation of a fluid tight seal are the goals of successful endodontic therapy.\(^1\) In order to create a fluid tight seal, it is imperative that the endodontic filling material closely adapts or bonds to the tooth structure. This, however, is impaired by the presence of a smear layer, which invariably forms after endodontic instrumentation.\(^2\),\(^3\) The smear layer contains organic material, odontoblastic processes, bacteria and blood cells.

Various materials and techniques have been reported with wide variations in their efficacy regarding the removal of the intra-canal smear layer.\(^2\),\(^4\) The most widely used chemical for the purpose is EDTA, used in different formulations.\(^5\) They have been reported to consistently produce canals with patent dentinal tubules.\(^6\) However, it has been found to be less efficient in narrow portions of the canal,\(^7\) it requires a long application time for optimum results\(^8\) and can seriously damage the dentin, if used in excess.\(^9\)

Clinically, endodontic procedures use both mechanical instrumentation and chemical irrigants in the attempt to three dimensionally debride, clean and decontaminate the endodontic system.\(^10\),\(^11\)

Even after doing this meticulously, we still fall short of successfully removing all of the infective microorganisms and debris. This is because of the complex root canal anatomy and the inability of common irrigants to penetrate into the lateral canals and the apical ramifications. It seems, therefore, appropriate to search for new materials, techniques and technologies that can improve the cleaning and decontamination of these anatomical areas.\(^12\)

Some of these mechanically activated irrigation techniques include manual irrigation with needles, K-file, Master cone GP points, Irrisafe, ultrasonics, Endo-activator, Rotobrush, Roeko-

<table>
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<th>TABLE 1</th>
<th>Subgroups depending on the final irrigant used.</th>
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<td><strong>GROUP I</strong> (Hand Activation)</td>
<td><strong>GROUP II</strong> (Er:YAG with PIPS)</td>
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<td>Sub Group A (5.25 % NaOCl)</td>
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<td>Sub Group B (17 % EDTA)</td>
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Fig. 1: Access opening. 
Fig. 2: Stainless steel 10# no. K-file for patency.
brush, etc. The newest of the lot is PIPS, i.e Photon-Induced Photoacoustic Streaming via laser. Hence it was chosen for the study.

**Material and methods**

Forty single-rooted, extracted human teeth were used in the study. Teeth with fractures, cracks or any other defects were excluded. Subsequently, they were scaled with ultrasonics for the removal of calculus or any soft-tissue debris, washed with distilled water and then stored in normal saline. Standard endodontic access cavity preparations were performed and then a stainless-steel #10 K-file (Mani K-File) was inserted into the canal until the tip was just visible at the apical foramen to check for patency. Chemo-mechanical preparation was done up to F3 using rotary protapers (DENTSPLY Maillefer) along with EDTA gel (Glyde – DENTSPLY Maillefer) for all the samples.

Irrigation of all the samples during preparation was accomplished using 5 ml of 5.25 % sodium hypochlorite between each file. Samples were then divided randomly into two groups, depending upon the method of activation of the final irrigant used.

These groups were further divided into two subgroups, depending upon the final irrigant used (Tab. 1):

- Subgroup A: 5.25 % NaOCl (n = 10)
- Subgroup B: 17 % EDTA (n = 10)

Activation of the irrigant for group I was done mechanically by agitating a stainless steel #25 K-file (2 % taper) in the canal when it was filled with the final irrigant solution.

An Er:YAG laser with a wavelength of 2,940 nm (Fotona) was used to irradiate the root canals in Group II with a newly designed 12 mm long, 400 µm quartz tip. The tip was tapered and had 3 mm of the polyamide sheath stripped away from its end. The laser operating parameters used for all the samples (using the free-running emission mode) were as follows: 40 mJ per pulse, 20 Hz, at very short pulse (MSP) mode, which provides the same 400 W of peak pulse power as the parameters recommended by Olivi (20 mJ, 15 Hz, SSP). The coaxial water spray feature of the handpiece was set to ‘off’ while air settings were kept at 2. The tip was placed into the coronal access opening of the chamber just above the orifice, and was kept stationary. During the laser irradiation cycles, the root canals were continuously irrigated with the final irrigant to maintain hydration levels using a hand syringe with a 25 gauge needle positioned above the laser tip in the coronal aspect of the access opening, according to the above protocol.

After preparation, the root canal walls were dried using paper points. Longitudinal grooves

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**Figures**

Figs. 3 and 4. Chemo-mechanical preparation up to F3.

Fig. 5. Group I – Hand activation using stainless steel #25 K-file (n = 20).

Figs. 6a & b and 7. Group II – Er:YAG activation using Photon-Induced Photoacoustic Streaming tip (n = 20).
were made on the distal and mesial root surfaces, preserving the inner shelf of the dentin surrounding the canal. Roots were then sectioned with the help of a chisel and mallet. Samples were then subjected to SEM to visualize the surface characteristics.

_Results_

Group I specimens (hand activation) consistently exhibited a thick smear layer with NaOCl (subgroup A, Figs. 8a–c) while comparatively less smear layer was observed with EDTA (subgroup B, Figs. 9a–c). SEM examination demonstrated that when NaOCl irrigation was applied, a noticeable smear layer and occluded dentinal tubules remained on the treated surface. Debris, defined as dentin chips and pulp remnants loosely attached to the internal surface of the root canals, was present in the specimens in subgroup A (Group I). In the specimens of EDTA, mostly open dentinal tubules were observed in the coronal and the middle third while in the apical third of all specimens occluded tubules were observed.

Group II specimens treated with the Er:YAG laser with PIPS showed the most effective removal of the smear layer from the root canal walls compared to Group I (hand activation) specimens. At higher magnifications (1,000x–2,000x) subgroup B (17 % EDTA) showed better results with exposed and intact collagen fibers and open dentinal tubules, even in the apical third (Figs. 11a–c), when compared with subgroup A (5.25 % NaOCl), where open dentinal tubules along with scattered dentinal chips were observed (Figs. 10a–c). None of the SEM images indicated signs of dentin melting.

_Discussion_

Current instrumentation techniques using rotary instruments and chemical irrigation still fall short of successfully removing the smear layer from inside the root canal system. Mechanical activation of the chemical irrigant plays an important role in removing the smear layer. Fiber-guided lasers have also been used hoping to achieve some
degree of success, however, there is limited availability of literature regarding this topic.

The concept of laser-activated irrigation is based on cavitation. Because of the high absorption of water by the mid-infrared wavelength of lasers, the cavitation process generates vapor-containing bubbles, which explode and implode in a liquid environment. This subsequently initiates pressure/shock waves by inducing shear force on the dental wall. In a water-filled root canal, the shock waves could potentially detach the smear layer and disrupt bacterial biofilms. To efficiently activate irrigant and generate shock waves in the root canal, lasers with wavelengths from 940–2,940 nm have been used.

5.25 % sodium hypochlorite was used in Group I because the majority of practitioners still use only sodium hypochlorite as the irrigant along with hand instruments. Hence sodium hypochlorite was used in Group I. To remove inorganic debris of the smear layer, use of aqueous EDTA had been recommended. But prolonged use of EDTA can cause dentinal erosion of the root canal by decalcifying the peritubular dentin. The recommended time in endodontic literature is only 1–2 minutes. Hence, 17 % aqueous EDTA was used for one minute in Group II to minimise time and damage.

The results of this study indicate that NaOCl subgroups could remove the smear layer in the coronal third; however, it did not remove the smear layer from the middle and apical third of the canal wall. EDTA is efficient in removing the smear layer, which is evident in this study for both groups. The effects of EDTA were limited to the coronal and middle third in Group I (hand activation) while it was effective even in the apical third for Group II (Er:YAG-PIPS). Ciucchi et al. stated that there was a definite decline in the efficiency of irrigating solutions along the apical part of the canals. This can probably be explained by the fact that dentin in the apical third is much more sclerosed and there are fewer dentinal tubules present there. Also apical reach, canal configuration, and smooth transition are a few of the anatomical key factors. Hence root canal success is dependent on apical third anatomy.

The Er:YAG laser used in this investigation proved to be more effective than the conventional technique in removing the smear layer. This finding can be attributed to the photomechanical effect seen when light energy is pulsed in liquid. When activated in a limited volume of fluid, the high absorption of the Er:YAG wavelength in water, combined with the high peak power derived from the short pulse duration that was used for five seconds (three cycles), resulted in a photomechanical phenomenon. A profound "shockwave-like" effect is observed when a radial and stripped tip is submerged in a coronal chamber above the orifice. As a result of the very small volume, this effect may remove the smear layer and residual tissue tags and potentially decrease the bacterial load within the tubules and lateral canals. By using lower sub-ablative energy (40 mJ) and restricting the placement of the tip to within the coronal portion of the tooth only, the undesired effects of the thermal energy, as previously described in the literature, was avoided. In the current study, the smear layer and debris were not removed by thermal vaporisation, but probably by photomechanical streaming of the liquids, which were laser activated in the coronal part of the tooth.

Giovani Olivi and Enrico DiVito have described this light energy phenomenon as photon-induced photoacoustic streaming (PIPS). The effect of irradiation with the Er:YAG laser equipped with a tip of novel design at sub-ablative power settings (20 mJ, 15 Hz, SSP, 400 W peak power) is synergistically enhanced by the presence of EDTA. This leads to a significantly better debridement of the root canal, contributing to an improvement in treatment efficacy. Hence, the PIPS technique resulted in pronounced smear layer removal when used together with EDTA and at the settings outlined.

**Conclusion**

Within the limitations of this study, the Er:YAG laser with PIPS showed significantly better smear layer removal than the hand-activation group. At the energy levels and with the operating parameters used, no thermal effects or damage to the dentin surface was observed. With the described settings, the Er:YAG laser produced a photomechanical effect, demonstrating its potential as an improved alternative method for debriding the root canal system in a minimally invasive manner.

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**Contact**

**Prof. Dr Vivek Hedge**
Professor and Head
Department of Conservative Dentistry and Endodontics
M A Rangoonwala Institute of Dental Sciences
Pune, India