



Rationale for using a double-wavelength (940 nm + 2780 nm) laser in endodontics: literature overview and proof-of-concept

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Abstract

Aim The goal of endodontic research is to report interventions, techniques or protocols that are most likely to deliver the outcomes that are of most interest to both clinicians and patients. The development of a double-wavelength laser delivered concomitantly and through the same radial firing tip (RFT) may provide a unique combination of beneficial properties that may clinically surpass all previously reported laser-assisted protocols. The aim is to present a rational literature overview that could support the adoption of simultaneous use 2780 and 940 nm wavelengths for smear layer removal and disinfection respectively.

Methods In order to provide relevant clinical data, two distinct clinical cases of relatively high endodontic complexity are reported with 1-year follow-up.

Results The results of both clinical cases show the immediate remission of symptoms, absence of clinical complications and complete radiographic healing.

Conclusions Together with the available amount of literature that could support the effectiveness of these two wavelengths to remove SL and to achieve deep dentin disinfection, it is possible to expect that this innovative combination of lasers delivered by RFT may be of high clinical relevance in the near future.

Keywords Er,Cr:YSGG laser · 940 nm diode · Double-wavelength · Endodontic outcome · Root canal treatment

Introduction

The success of endodontic therapy is found to be dependent on the ability to clean and disinfect the complex root canal system effectively [1].

However, the intricate anatomy of the root canal system, the microorganisms' invasion of dentinal tubules and the smear layer that is produced during instrumentation can be considered major obstacles for complete elimination of bacteria. The smear layer (SL) contains inorganic and organic substances, including microorganisms and remnants of necrotic debris [2–4] or providing itself a reservoir of irritants [5, 6].

Chemical irrigants such as sodium hypochlorite (NaOCl), chlorhexidine (CHX), ethylenediaminetetraacetic acid (EDTA) and MTAD (mixture of doxycycline, citric acid, and a detergent) are often used during cleaning and shaping but none of these irrigants has the characteristics of an ideal irrigant [7].

It is well known that the root canal apical third imposes a special challenge to irrigation and the balance between safety and effectiveness in this area is of particular importance [8]. The diffusion of these irrigants through the dentin is slow and may depend on several factors (e.g., temperature, concentration). Moreover, convection mechanisms during irrigant flow deliver frictional forces between the irrigant and the root canal wall (wall shear stress). Different irrigation solutions and techniques have been tested but, so far, the clinical extent of their chemo-mechanical cleaning effects of the root canal system is still a source of debate [9].

While trying to overcome their individual limitations, several protocols propose to mix or alternate between different irrigating solutions. However, several antagonistic interactions between irrigants were to be found, including the loss of free available chlorine for NaOCl when in contact with chelants,

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which consequently reduced the tissue dissolution capability and to a lesser extent antimicrobial activities. When used in combination, both CHX–EDTA and CHX–NaOCl cause precipitates that present detrimental consequences [10]. As a consequence, sterile water or saline are advocated to neutralize such interactions [8].

Despite NaOCl and CHX generally exhibiting good bactericidal properties [11, 12], calcium hydroxide (CH) is often preconized as an additional inter-appointment canal medication to overcome persistent infections. However, current clinical evidences are not able to support that multiple appointment treatments concomitant with the use of CH could provide better endodontic outcomes [13–15]. Moreover, it was demonstrated that even using a laser-assisted technique, no technique or irrigation regimen was able to effectively remove CH from the root canal irregularities [16].

Clinical data regarding both NaOCl and CHX for root canal disinfection is still conflicting and current clinical evidences are still not able to support any individual irrigation strategy. Thus, the overall available evidence on this topic is scarce and often fails to report potentially patient-relevant outcomes or even reliable guidelines for treating apical periodontitis [12, 17, 18].

Lasers have long been presented as promising alternatives to conventional chemical irrigation procedures in endodontics [19, 20]. However, the biophysical properties of each wavelength are essential to determine their possible applications/limitations and to understand how they can beneficially be used in combination.

Generally, mid-infrared erbium lasers operating at wavelengths of 2780 or 2940 nm demonstrate a high absorption coefficient for both water/aqueous solutions and hydroxyapatite whereas in the near infrared range diode lasers (810, 940, and 980 nm) are mostly absorbed by haemoglobin and melanin [21–24].

As each laser wavelength has a specific absorption coefficient for every tissue [25], their role in endodontics should be focused in two main goals: (1) debris and SL removal and (2) bacterial eradication from the root canal system and within deep dentin layers.

The 940-nm diode laser

Near-infrared lasers (NIR; 800–980 nm) are predominantly absorbed by melanin and haemoglobin, presenting high transmission through water [26]. Their high transmission into water allows near-infrared lasers to penetrate deep into dentine and interact with the bacterial cell walls. Apart of bacterial wall pigmentation, their sensitivity to short periods of temperature increments was considered crucial as regards to their survival [27].

As endodontic pathogens present pigments such as melanin in their bacterial membranes, diode lasers have been demonstrated great bactericidal ability by directly interacting with bacterial pigmented membranes [28–30] or even with the bacterial microenvironment, most likely in the form of heat [31].

The 810 nm and 940 m lasers present similar low absorption coefficients in water ($\mu_a = 0.04\text{--}0.05\text{ cm}^{-1}$) whereas the 980-nm diode laser presents a slight absorption coefficient peak in water ($\mu_a = 0.25\text{ cm}^{-1}$) [22]. Knowing that the root canal dentin presents high volume of water content within its molecular structure, such water peak absorption constrains 980-nm dentine penetration when compared with the other two NIR wavelengths (810 and 940 nm). Consequently, having lower absorption coefficients in water, it should be expected that both 810 and 940 nm lasers could present better biophysical behaviour in terms of dentine penetration and deep disinfection in detriment of the 980 nm laser [22, 32, 33].

Based on the same biophysical properties—despite questionable conflicting findings in literature [34–37]—it cannot be expected that any diode laser could effectively remove smear layer and expose dentinal tubules without exciding the dentin temperature threshold [36, 38–41]. In literature, the effects of NIR lasers on SL removal are highly inconsistent and often found to be highly dependant on the final irrigation regimen [42–45].

It cannot be also expected near-infrared lasers to activate irrigants such as NaOCl, citric acid or EDTA as their absorption coefficients in such solutions range only from $\mu_a = 0.05\text{--}0.25\text{ cm}^{-1}$ [22] and an average penetration into intra-canal irrigants between 4 and 20 cm. Therefore, cavitation effects using these wavelengths should not be expected. As a consequence, the use of a any diode laser as a single wavelength for endodontic treatments often fail to show any beneficial effects on adhesion of endodontic sealers to the root surface nor to reduce apical leakage [36, 37, 46–49]. Moreover, only output powers up to 1 W in continuous wave (CW) have shown to have no impact to the dentine structure of the main canal walls [50].

Despite inconclusive findings regarding SL removal properties, diode lasers have long been proposed as an effective strategy to disinfect the root canal system [38], with the additional advantage that unwanted temperature rise was found to be less than with Nd:YAG laser [51].

Several reports can attest the safeness of NIR lasers regarding the minimal increase of intra-canal temperature and their effects on surrounding periodontal structures [52]. However, to totally overcome any possibility of hazardous temperature increment and to cover the maximum area for bactericidal purposes, the ideal protocol for using diode lasers should include circular movements while withdrawing the fibre from the apex to coronal direction [38–41, 50, 53–56]. Despite not

being mandatory, cooling with irrigation between irradiations was also found to be more effective than the passive cooling during resting time [57].

As diode lasers are characterized to have low absorption in dentin, their biggest advantage relies on how they can be highly effective for deep root canal decontamination. As NIR light is able to penetrate deep into dentinal tubules, bacterial eradication has been demonstrated to be significant up to 1000 μm [32, 58–62]. In addition, it has recently been shown that intra-canal disinfection with a 940-nm laser may have a positive bactericidal effect on bacteria present beyond the apex [63].

Thus, despite several bias mostly related to the methods and protocols adopted, there is a substantial amount of literature that is able to support the use of both 810 and 940 nm lasers with or without the adjunctive use of irrigants to assist and improve root canal disinfection [33, 40, 41, 54, 58, 62, 64–69].

The 2780-nm Er,Cr:YSGG laser

The rationale for using erbium lasers in endodontics may be briefly described as (1) the ability of infrared light to interact with aqueous solutions and produce cavitation effects capable to remove smear layer, dentinal debris and filling materials from the root canal walls [70–73] and (2) the ability of infrared light to propagate into the dentinal tubules, achieving significant bactericidal effects deeper than conventional chemical solutions [30, 74].

Since 1999, the 2780-nm Er,Cr:YSGG laser has been reported as an effective method for smear layer and debris removal [75]. Then, in the early 2000s further investigations have confirmed its potential for such application and found the relevance of water to mediate the SL ablation [76–81]. The laser-water-mediated cavitation (expansion and implosion of vapour bubbles with secondary cavitation effects that induced shear stress forces towards the main root canal) was in 2006 described as the mechanism responsible for such effective results [82].

In comparison with EDTA irrigation, hand activation or even ultrasonic-activated irrigation, the cavitation effects mediated by the Er,Cr:YSGG laser have been consistently providing superior SL removal effectiveness [70, 83–86], resulting in a significant clearance of canals/isthmuses prior obturation [87] and less microleakage following obturation [88].

As regards to the endodontic repairing materials, it was shown that the use of the Er,Cr:YSSG laser did not affect the highest adhesion properties of MTA when compared with bioactive obturation materials [89].

The bactericidal properties provided by erbium lasers are concomitantly attributed to either instant evaporation of

intracellular water or bacterial dehydration [30, 90], without promoting significant or hazardous temperature changes [81]. In addition, the Er,Cr:YSGG laser has also been shown to be effective for deep root canal dentin disinfection [74, 91–93].

Being non-thermal in nature, the Er,Cr:YSGG laser irradiation has been reported to produce clinically safe temperature increments along the root canal walls [80, 81, 94–97], together with the absence of molecular dentine changes [98, 99], signs of melting or carbonization [23, 78, 81, 98].

Endodontic radial firing tips

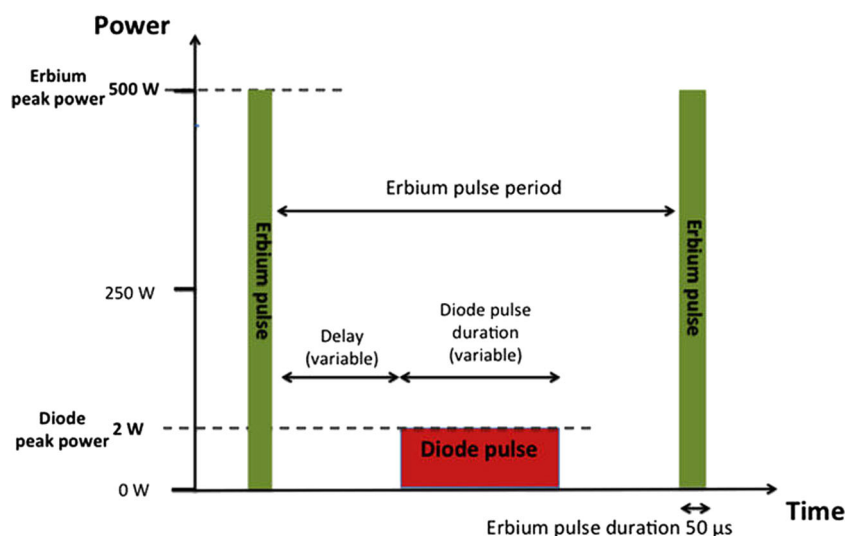
Previously, laser-assisted endodontic protocols consisted of using plain fibres (with a straightforward emission beam profile). Generally, these fibres were placed in the main canal and withdrawn from apical to coronal in a rotating motion. However, such technique is known to be technique sensitive and to produce rather inconsistent results [23, 95, 100].

Moreover, direct emission of laser irradiation from the tip of the optical fibre could result in energy transmission beyond of the apical foramen being theoretically hazardous in teeth with proximity to the mental foramen or mandibular nerve. It was reported that while using plain laser fibres in combination with irrigants, apical extrusion might also occur even under sub-ablative settings [84, 101].

Designed to overcome such limitations, radial firing tips (RFT) present a beam expansion pattern—promoted by the tip geometry—that favours a homogeneous energy distribution along the root canal wall [84, 85, 102]. In contrast with plain fibres, RFT have been shown to produce consistently relevant *in vitro* [102, 103] and clinical [104, 105] findings. They are known to spread its energy along to the direction of the dentinal tubules [74], to produce lower temperature increments [85], to increase cavitation effects towards the root canal walls without harming apical tissues [85, 106], to be highly efficient in bacterial and biofilm reduction [107, 108] and to allow irrigating solutions to travel apically by overcoming the airlock effect [109].

Despite the well-reported *in vitro* advantages of several lasers in endodontics, the Er,Cr:YSGG laser is the only one supported by clinical data demonstrating its potential benefits and long-term outcomes [104, 105, 110]. Lately, a dual-wavelength approach using two lasers in combination through the same fibre has been reported as a safe, promising concept to be incorporated for root canal therapy (Fig. 1). The rationale for adopting such technology is to incorporate the biophysical background of both Er,Cr:YSGG and 940-nm lasers. Being delivered by the same hand piece and though RFT, it may be considered a promising tool to surpass the limitations of both wavelengths, combining their beneficial properties and thus being able to provide superior outcomes [111, 112].

Fig. 1 Schematic view of the alternating pulses of Er,Cr:YSGG and 940-nm diode lasers, emitted through one radial firing tip. Adapted from [111]



As the report of clinical cases with long-term follow-ups is highly encouraged to demonstrate new treatment concepts prior the elaboration of randomized clinical trials [113], the aim of reporting the following two clinical case reports is to provide a proof-of-concept and possibly support the use of double-wavelength lasers in endodontics.

Case report #1 A 67-year-old male patient presented for consultation complaining of recurrent swelling and fistula tract related to the tooth 41. The patient's medical history was not contributory. After performing clinical and radiographic examinations, the diagnosis was compatible with root canal necrosis and asymptomatic apical periodontitis (AP). At the time of consultation, the tooth was slightly tender to percussion and mobility grade I (Fig. 2a, b). Periodontal probing depths were considered normal (< 3 mm).

Radiographic images were taken immediately following obturation (Fig. 3) and radiographed for control after 6 (Fig. 4) and 12 (Fig. 5) months.

Case report #2 A 47-year-old female patient presented for consultation complaining of increasing persistent pain related to tooth 47. The tooth was supporting a metallic-ceramic bridge supporting the importance of performing a successful root canal treatment. The patient's medical history was not contributory. After performing clinical and radiographic examinations, the diagnosis was compatible with root canal necrosis and symptomatic AP. At the time of consultation, the patient was using anti-inflammatory medication regularly but the tooth was still tender to percussion, having no mobility (Fig. 6). Periodontal probing depths were considered normal (< 3 mm). The C-shape configuration of the root canal system could be confirmed under the microscope (Fig. 7).

Radiographic images were taken immediately following obturation (Fig. 8) and controlled after 6 (Fig. 9) and 12 months (Figs. 10 and 11).

Treatment protocol

Treatment options were discussed, and the required consent obtained (Helsinki Declaration, revised in Edinburgh (2000)). No financial incentive was offered (i.e. patients were responsible for the usual root canal treatment fee).

Under local anaesthesia (2% lidocaine with 1:100,000 epinephrine (Scandonest, Saint Maur des Fossés, France)) and rubber dam isolation (Hygenic Non-Latex Rubber Dam, Coltène/Whaledent, Germany), an access cavity was prepared with a high-speed carbide bur (SS White, Lakewood, USA). The working length (WL) was electronically established



Fig. 2 a, b Case #1 initial radiograph and clinical picture of the tooth #41 together with guta percha indicating the presence of the fistula tract and AP

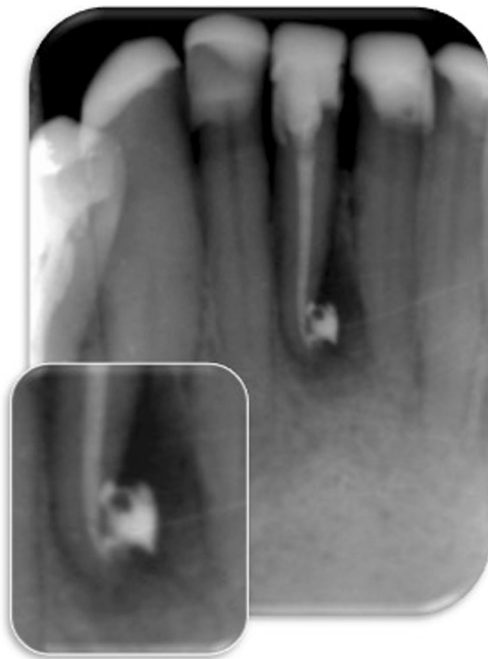


Fig. 3 Case #1 final radiograph following the completion of the double-wavelength laser-assisted treatment. To be noticed is the apical delta completely debried and sealed

(Root Zx, Morita, Japan) as 1 mm short of the biological apex of the root and confirmed by radiography. Patency was confirmed with an ISO#15 K-file, and root canal preparation was performed using the Protaper Next system (Dentsply-Maillefer, Ballaigues-Switzerland) up to an X3 (#30.07) instrument for each canal. Syringe root canal irrigation

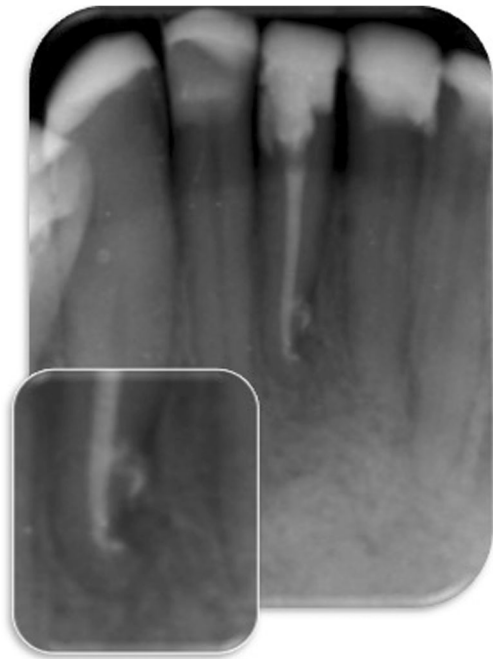


Fig. 5 Case #1 radiographic assessment with a 12-month follow up. To be noticed is the complete regression of the AP and re-establishment of the periodontal structures

(Monoject 27G, Kendall-Covidien, USA) was performed with 3 mL of sterile saline solution between each file.

No chemical irrigants or inter-appointment dressings were used. For smear layer removal and root canal disinfection, a double-wavelength protocol was adopted.

Following root canal preparation, each canal was filled with distilled water and laser irradiation was concomitantly performed with the 2780-nm Er,Cr:YSGG laser and 940-nm diode laser (Biolase Technology, Irvine, CA, USA). While using a 270- μ m Radial Firing Tip (RFT2, Biolase Technology; calibration factor of 0.55), the Er,Cr:YSGG laser was used with panel settings of 1.25 W, 50 Hz (25 mJ), 60 μ s pulse 80% water and 30% air, while the 940-nm diode laser was operating at 1 W, continuous wave (CW).

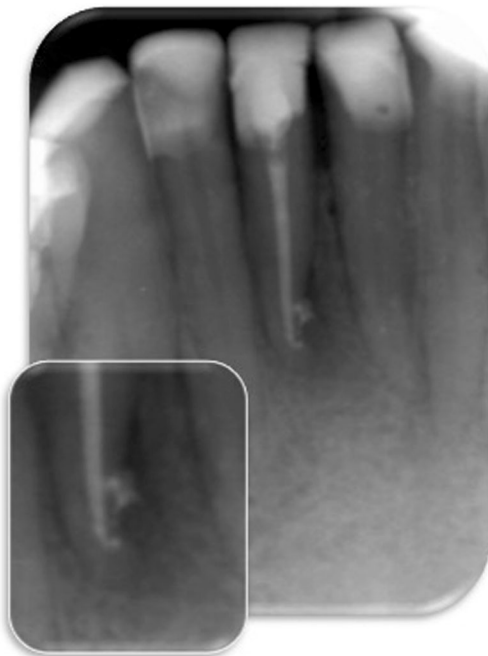


Fig. 4 Case #1 radiographic assessment with a 6-month follow-up

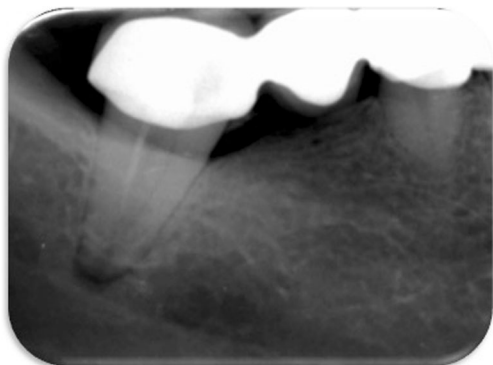


Fig. 6 Case #2 initial radiograph of the tooth #47 demonstrating the absence of apical constriction due to inflammatory resorption, the AP and the proximity to the mandibular nerve

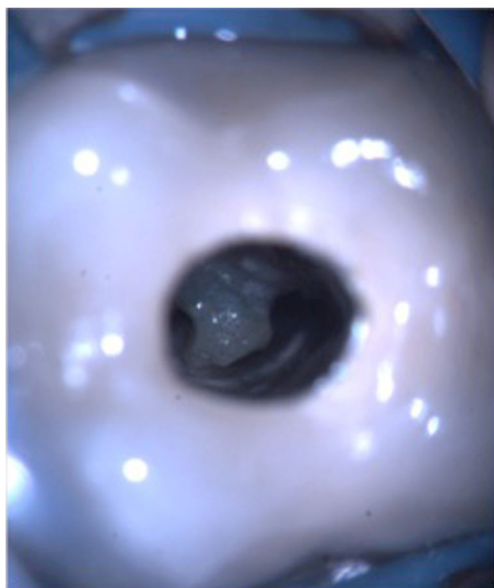


Fig. 7 Case #2 picture taken under operating microscope at 12.5X magnification (ZeissPico, Switzerland) demonstrating the C-shape configuration of the root canal system

The tip was placed up to the working length and irradiation was performed, approximately, at the speed of 2 mm/s until it reached the most coronal part of the canal. The irradiation procedure was repeated four times with approximately 15 s between each irradiation. Afterward, a sterile cotton pellet was placed in the pulp chamber, and the access cavity was sealed with glass ionomer restorative material (KETAC Molar Aplicap™, 3M ESPE, USA).

At the second appointment (after 2 weeks), there were in both cases negative histories on questioning to pain. Moreover, tenderness to percussion (and fistula tract in case #1) has disappeared completely.

Under local anaesthesia and rubber dam isolation, the canal was re-accessed. The main canals were filled with distilled

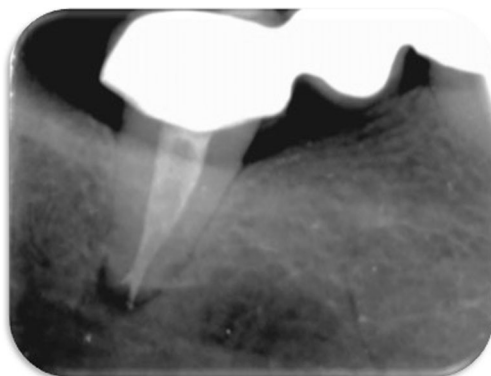


Fig. 8 Case #2 final radiograph following the completion of the double-wavelength laser-assisted treatment. To be noticed are the isthmuses between the two main canals and the apical delta completely debried and sealed

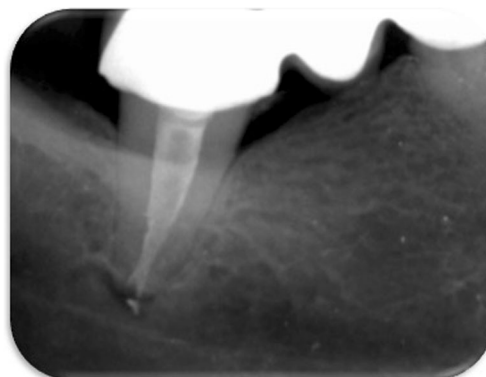


Fig. 9 Case #2 radiographic assessment with a 6-month follow-up

water and laser irradiation was performed using the double-wavelength protocol identical to the first appointment. After irradiation, the canal was dried with isopropyl alcohol and sterile paper points while checking for the absence of any suppuration or exudate.

Filling was performed using the continuous wave of condensation technique (Elements™, Kerr Dental, USA) with an X3 (#30.07) auto-fit gutta-percha cone (Dentsply-Maillefer, Ballaigues-Switzerland), and a resin-based endodontic sealer (Topseal, Dentsply-Maillefer) [114].

Restoration of the access cavities was performed using Ionoseal (VOCO GmbH, Germany), SureFil SDR (Dentsply, USA), and composite (Filtek, 3M ESPE, USA).

Results

In case #1, immediately after obturation, it could also be noticed that the presence of an apical delta, including lateral canals at the apical third, were completely cleaned and obturated (Fig. 3).

As regards to case #2, the presence of a C-shape canal connecting the two main canals could be completely debried

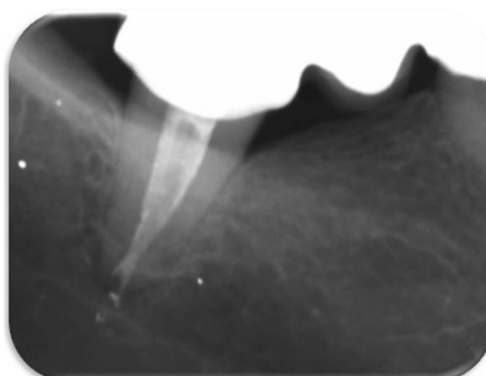


Fig. 10 Case #2 radiographic assessment with a 12-month follow-up. To be noticed the complete regression of the AP and re-establishment of the bone structure around the mandibular nerve



Fig. 11 Case #2 clinical picture demonstrating the presence of regular occlusal load and good periodontal condition at 12 months

and the connecting isthmuses were successfully sealed (Figs. 7 and 8). Although with the absence of an apical constriction (such apical configuration could be a possible factor for any extrusion of irrigants and iatrogenic accidents), the apical third was effectively cleaned and completely sealed. To be noticed, the proximity to the mandibular nerve could have represented an additional challenge in case of performing traditional irrigation regimens. The tooth remained in function during the treatment and follow-up period (Fig. 11).

In both clinical cases, there was an absolute remission of symptoms after the first appointment. Continuous radiographic regression of the AP could be observed following the completion of the double-wavelength laser-assisted treatment and throughout the 12-month follow-up period. Moreover, after 12 months, there were evident radiographic signs of positive changes in bone density (trabecular reformation followed by lamina dura formation) (Figs. 5 and 10). Clinical signs and symptoms disappeared completely and a healthy periodontal status could be confirmed, indicating the successful endodontic outcomes in both cases.

Discussion

One of the most important factors affecting the prognosis of an endodontic treatment is the preoperative presence of AP due to the lower success rates when compared with normal teeth radiographic appearance [115, 116]. Due to the fact there are still missing clinical guidelines for treating teeth with AP, further research is continuously demanded to highlight which are the protocol-related factors that can interfere with endodontic outcomes [18].

It was shown that there are no significant differences in healing of AP when comparing obturated and non-obturated teeth after instrumentation, and it appears that the quality of

root canal filling does not directly interfere with endodontic outcomes. Hence, the success of an endodontic treatment ultimately depends on the elimination of the microorganism, host response and coronal seal of root canals [117, 118]. Other possible predictive factors such as age, gender, tooth type, root-end filling material and magnification type had no significant effect on the proportion of success [119].

Both case reports presented a follow-up period of 12 months following the completion of the endodontic therapy. After 1 year of follow-up, the (re)emergence of apical periodontitis may not be directly related to the endodontic treatment itself but to extrinsic factors such as quality of obturation or coronal seal [120]. Therefore, the adoption of 12 months as end-point to establish the course of an endodontic outcome is highly recommended.

For the above-mentioned clinical cases, there were no medication prescriptions during or following the treatment. Antibiotics are currently overprescribed for the management of endodontic infections such as symptomatic irreversible pulpitis, necrotic pulps and localized acute apical abscesses. However, it is highly recommended that the primary aim while treating teeth with AP and localized swelling or pain is to achieve drainage and disinfection without additional use of antibiotics [121, 122]. Despite being limited to two clinical cases, laser-assisted endodontic treatments may support and corroborate this position statement.

Several reports can be found in literature using distinct laser wavelengths for endodontic purposes. In their vast majority, the emission pattern of laser energy is directed along to the main root canal due to the bare-end configuration of endodontic fibres. To overcome this limitation while using straight forward emitting fibres, circular movements during irradiation are proposed by several investigations. Nevertheless, such rotational movements still do not allow to predictably obtain a uniform coverage of the entire the root canal system [100].

It was long reported that lateral emission could tri-dimensionally cover the entire root canal system and penetrate directly into distinct anatomic configurations as well as within the dentinal tubules [123]. The present report used radial firing tips that are shown to be useful in cleaning and tri-dimensionally disinfecting both intricate root canal anatomies.

In contrast with the previous reports using RFT in straight canals of the anterior teeth [104, 110], the RFT used in these two clinical cases were moved in a spiralling motion along the root canal walls. The aim was to facilitate the fibre withdrawing motion and to possibly overcome any ledging that may occur in apical thirds of curved canals. In fact, it is known that the effect of the laser may vary accordingly to different foramina sizes and dentin width [63] and these factors should be taken into high consideration while selecting an appropriate protocol for specific clinical conditions.

The two clinical cases in this report presented wide apical configurations. The apical foramen can be wide due to over instrumentation, root-end resection, incompletely formed root apex or inflammatory root resorption of endodontic origin [124]. Such apical configurations can attest the importance of adopting an alternative strategy to conventional and possibly hazardous irrigants such as NaOCl. The use of the Er,Cr:YSGG laser with low power outputs is able to drive irrigation solutions to the tip of the canal without harming apical tissues [106]. The use of Er,Cr:YSGG laser, RFT and distilled water as an irrigant surely prevents any possible iatrogenic damage. This may be of an additional importance in case of proximity of sensitive structures such as the mandibular nerve as in case #2. The fact that both patients did not have any postoperative pain might attest the safeness of the adopted protocol relatively to wide apical configurations.

Still regarding to the use of endodontic fibres, one should have taken into consideration that the power emitted on the distal end of the fibre may not be always the same as the one presented on the display due to the calibration factor of the fibre [53]. The RFT2 tips used in both clinical cases present a calibration factor of 0.55. This would mean that for 1.25 and 1 W used for Er,Cr:YSGG and diode lasers, the output powers are 0.69 and 0.55 W respectively.

In accordance to evidence-based clinical evidences, no intra-canal medication (e.g. calcium hydroxide) was placed between appointments. The clinical use of CH is controversial, but as regards to the removal of CH from the root canal walls, the Er,Cr:YSGG laser-activated irrigation may significantly be more effective than other irrigation regimens. However, no technique was able to remove the CH dressing completely [16].

To achieve predictable disinfection levels, two wavelengths were used simultaneously. Both 2780- and 940-nm lasers have been shown to be powerful tools in cleaning and disinfecting root canals. According to each wavelength, it has been demonstrated that dentinal tubules may act as optic channels, redirecting and transmitting laser light deeply in multiple directions [125]. This might be supported by the clearance consequent sealer penetration within secondary lateral canals together with the successful healing of the periapical structures in both clinical cases.

As diode lasers under 1 W do not interfere with the dentin micro-structure and that the Er,Cr:YSGG laser produces SL-free canals with open dentinal tubules, the use of resin-based sealers following laser-assisted endodontic procedures is advocated [47, 126]. In the present case report, and in similarity with the available clinical data [104, 105, 110], the use of a resin-based sealer (Topseal, Dentsply-Maillefer) has demonstrated high affinity for dentin penetration and hermetic seal.

The possibility of using two distinct lasers with two complementary effects (cavitation-induced debris and SL removal by the Er,Cr:YSGG laser and the superior dentin penetration/disinfection of the 940 nm diode) seems a very promising and logical combination. In addition, the possibility to deliver both wavelengths through the same radial firing tip guarantees the tri-dimensional coverage of the entire root canal system and allows directing both lasers into intricate root canal configurations.

In practically all levels of evidence (LOE) classification systems, randomized controlled trials (RCTs) are considered as a high LOE, as opposed to case reports and case series that are considered as a low LOE [127–130]. However, from the clinical perspective, the study design and the ensuing LOE classification as a decisive factor for the evidence appraisal can be misleading.

Traditional LOE grading systems often fail to provide any information regarding the relevance of the investigated clinical question to the practitioner's decision-making. Thus, not only the strength of the evidence should be considered but also the clinical significance and relevance of the evidence. Occasionally, an RCT may be less significant to the clinical decision-making than a case series study, i.e. when a clinician assesses the benefits and risks of a possible treatment modality [131] such as the risk represented by proximity of the mandibular nerve (case #2). Therefore, different types of questions may require different types of evidence and both significance and relevance of the evidence seems to be more intuitive and subjective [132].

As clinical significance can be defined as “the practical or applied value or importance of the effect of an intervention”, treatments that produce reliable effects may be quite different in their impact on patients' function [133], the clinical significance of double-wavelengths laser-assisted endodontic treatment in terms of outcomes, safeness, time consuming, etc., may attest the importance of further report clinical cases, namely under different clinical scenarios. Hence, there is the aim to continue reporting clinically relevant data to enhance level of evidence of these promising but yet preliminary findings.

Conclusion

The goal of decision-making in healthcare is to choose the interventions that are most likely to deliver the outcomes that are of most interest to patients while preventing possible harmful outcomes [134]. With this manuscript, the aim was to demonstrate that laser-technology is in far expansion within the endodontic field and that with double-wavelength lasers, clinicians should expect to achieve highly predictable outcomes and less iatrogenic complications even in the most

complicated endodontic scenarios such as in multi-rooted teeth with unfavourable anatomies, associated with AP. To provide higher level of evidence that may corroborate these preliminary clinical findings further investigations are encouraged.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent (Helsinki Declaration, revised in Edinburgh) was obtained from all individual participants included in the study.

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