study
Torsional resistance of two nickel-titanium rotary instruments

materials
Clinical applications of mineral trioxide aggregate in endodontics

case report
Managing refractory endodontic disease with radial apical cleansing
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Welcome to the winter issue of roots!

You are going to learn quite a bit about endodontics and enjoy this issue, which is full of excellent articles from several of the leading global endodontic speakers, including Prof. Gianluca Gambarini, who will be speaking at ROOTS SUMMIT in Prague in May 2020. You will also be treated to an interesting and clinically applicable article from Dr Antonis Chaniotis, whom we had the pleasure of learning from at ROOTS SUMMIT 2016 in Dubai. There is also a terrific article from a regular participant in our online forum, Dr Justin Kolnick. Other articles in the magazine follow the same theme in that they concern scientifically based, clinically relevant endodontics that will help you in your day-to-day practice.

As roots is the official magazine of ROOTS SUMMIT, you can expect to see more articles in subsequent issues from the people you know. We plan to feature and highlight the clinical work and academic research done by our speakers and members of the RootsEndo Facebook group. Our Facebook group has more than 28,000 members with a keen interest in endodontics, including most of the top endodontic lecturers and clinicians from around the world. Several of these members have already had articles included in various issues of roots, and we hope that they will continue to write more for us.

It has long been the feeling of the ROOTS SUMMIT committee, starting with our scientific director, Dr David E. Jaramillo, that there is a need for more places for scientific studies to be published and read. The publishers of roots agree. Starting with the next issue, Jaramillo will be publishing clinical abstracts in addition to articles by the clinicians and academics who will be on the programme at ROOTS SUMMIT. Participants who have submitted poster or case presentations will also be featured. We can all agree that there needs to be a place for this important contribution to the profession to be acknowledged, shared and absorbed.

ROOTS SUMMIT has long been acknowledged to have one of the more scientifically significant programmes in endodontics and we look forward to raising the scientific level even higher with roots.

In closing, I would like to add a few words that we hope will encourage you to consider attending our meeting. ROOTS SUMMIT is different from most other events in two ways. One, the speakers are chosen according to the theme of the programme at the entire discretion of ROOTS SUMMIT committee. The second major difference is that the lectures are held in one room, allowing all participants to enjoy the same programme. This often leads to some very lively discussions during the breaks and the evening social events. More information about our outstanding programme of hands-on workshops and extensive lecture programme can be viewed at www.roots-summit.com.

We look forward to you joining us in Prague at ROOTS SUMMIT 2020, which is going to be held from 21 to 24 May.

Steve Jones
Guest Editor
editorial
Welcome to the winter issue of roots!
Steve Jones

study
Torsional resistance of two nickel-titanium rotary instruments
Prof. Gianluca Gambarini

technique
Maximum curve control
Dr Antonis Chaniotis

materials
Clinical applications of mineral trioxide aggregate in endodontics
Drs Arnaldo Castellucci, Matteo Papaleoni & Francesca Cerutti

research
Effect of duration of Er,Cr:YSGG laser etching on dentine morphology
An in vitro study
Drs Farnaz Mahdisiar, Alireza Mirzaei, Alireza Fallah, Saeedeh Akhoundan & Prof. Nobert Gutknecht

industry
SSP/SWEEPS endodontics with the SkyPulse Er:YAG laser
Dr Tomaž Ivanušič

case report
Managing refractory endodontic disease with radial apical cleansing
Dr Justin Kolnick

practice management
Successful communication in your daily practice
Part IX: Boosting a new employee’s performance
Dr Anna Maria Yiannikos

feature
A visit to VDW, a true child of Munich

meetings
ROOTS SUMMIT 2020: Registration is now open
International events

about the publisher
submission guidelines
international imprint
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Torsional resistance of two nickel-titanium rotary instruments: A comparative study

Prof. Gianluca Gambarini, Italy

Introduction

The main mechanisms of nickel-titanium (NiTi) endodontic instrument fracture have been revealed to be two modes of failure, one being torsional failure and the other cyclic fatigue. The former contributes to a significant proportion of failures. Cyclic fatigue fracture is caused by repetitive compressive and tensile stresses on the outermost fibres of a file rotating in a curved root canal, and torsional failure occurs when the tip of the instrument binds to the canal wall, even in a straight root canal.

Cyclic fatigue resistance of NiTi instruments has been assessed extensively. In contrast, there is less information available on torsional fracture resistance tests. The main method of testing for static rotational fracture is the comparison of the torsional resistance of the instruments as described by ISO 3630-1. According to this specification, the last 3 mm of the file tip must be fixed with brass and a rotational speed of 2 rpm applied to create a continuous torsional load until fracture occurs.

Torsional load can be limited during intra-canal rotary instrumentation by the torque-controlled endodontic motor: torque settings can be selected to prevent excessive torsional load on the instruments. It has been shown that the correct preset torque value for each instrument is very difficult to determine. If too high (the same happens when the clinician applies maximum torque), safety becomes dependent on the clinician’s skill in avoiding over-engagement and/or blockage of the file. If too low, the rotary instrument will be loaded by repeated locking and release through use of the torque-controlled motor or auto-reverse function. However, in narrow canals, where instruments are subject to higher torsional stresses than in wider canals, the chance of experiencing these repetitive torsional loads is increased.

To this point, torque value at failure according to the ISO test has not been commonly used to determine torque settings in torque-controlled motors. In most cases, values are higher than torque at failure. As a consequence, the concept that the use of a preset torque value is considered safe (i.e. capable of preventing shear fracture of the instrument) is not completely accurate. Therefore, NiTi rotary instruments should ideally exhibit good resistance to torsion in all cases and in curved canals should also be flexible and resistant to cyclic fatigue.

Many factors can affect resistance to torsion, including design, dimensions, manufacturing process and motion. In the present study, two NiTi rotary instruments, similar in dimension and design, were tested to compare torque at failure. The null hypothesis was that differences related to the different manufacturing processes would be found.

Methodology

Instruments from the following two different systems were tested and compared: ProTaper Next (Dentsply Maillefer) and EdgeFile X7 (EdgeEndo). For each system, ten
17/04 instruments were subjected to a repetitive torsional test. The test was performed using a torque-controlled endodontic motor (MASTERsurg, KaVo). The motor allowed precise recording of torque values during the instruments’ use. The accuracy and reliability of the device had been validated in a previous study. To perform the test, the apical 3 mm of each file was firmly secured, embedded in a resin block produced with a mixed auto-polymerising resin (DuraLay, Reliance Dental Manufacturing). Each file was then rotated clockwise at a speed of 300 rpm until fracture occurred. The torque limit was set at 5.5 Ncm, to ensure recording measurements ranging from 0.1 to 5.5 Ncm. The torque values at failure were recorded by the integrated software of the motor and analysed using spreadsheet software. The data was analysed using one-way analysis of variance and a Tukey test with a significance level of \( \alpha = 5\% \).

Results

Table 1 shows the results from the present study. The ProTaper Next files demonstrated no significantly different resistance in terms of maximum torque at failure compared with the EdgeFile X7 files (\( p < 0.05 \)). Similarly, no statistically significant differences were found between the two instruments in terms of time to failure (\( p < 0.05 \)).

Discussion

The ISO torsional resistance static test was developed more than 50 years ago to test manual stainless-steel instruments and is probably not ideal for testing rotary instruments that rotate at speeds much higher than 2 rpm or for the specific motors with torque control and auto-reverse mode. Therefore, in the present study, torsional resistance was assessed by using a different speed: the clinical one (300 rpm).

The tested instruments were similar in dimension and design, but had been produced through different manufacturing processes (alloys and heat treatments). According to the manufacturer, EdgeFile X7 files exhibit a higher flexibility and a greater resistance to cyclic fatigue than competitors’ instruments do. In stainless-steel instruments, flexibility and torsional resistance are usually inversely proportional. This is mainly due to the mass and/or dimensions of the instruments. The greater the mass, the more rigid and resistant to static torsion the instrument is. In the present study, mass and dimensions were very similar and torsional resistance too was similar, showing no statistically significant difference between the two instruments. The null hypothesis was therefore rejected.

Hence, the present study showed that heat treatment does not significantly influence torsional resistance, in contrast to the high increase in flexibility and fatigue resistance derived from heat treatment as reported in many published articles.

Editorial note: A list of references is available from the publisher.
The ultimate aim of endodontic therapy is the prevention of periradicular disease and the promotion of healing. To achieve these objectives, mechanical instrumentation and chemical disinfection are considered the basic principles, and the former essentially determines the efficacy of all subsequent procedures.

For gutta-percha fillings, the shaping of the canal should satisfy the following criteria:
- the shape of the main root canal should resemble a continuously tapering funnel from orifice to apex;
- the cross-sectional diameter of the main canals should narrow apically;
- preparation should follow the original shape;
- the position of the apical foramen should be preserved;
- the dimensions of the apical opening should be retained as far as possible.

The biological objectives of root canal instrumentation are:
- confinement of instrumentation to the limits of the roots themselves;
- avoidance of extruding necrotic debris into the periradicular tissue;
- removal of all organic tissue from the main and lateral canals; and
- creation of sufficient space to allow irrigation and medication by simultaneously preserving enough circumferential dentine for the tooth to function.

Achieving the aforementioned objectives in straight canals is considered a straightforward procedure. However, the internal anatomy of human teeth often consists of a highly complicated network of multiplanar curved and anastomotic canals. Reaching the biological and design objectives of root canal instrumentation in severely curved canal systems thus might be extremely challenging. Problems arise when canals are severely curved or even bifurcated and anastomotic (Fig. 1). In such teeth, the basic endodontic techniques and instrumentation protocols might be challenging to follow. For a safer and more predictable instrumentation, a newly introduced NiTi file sequence can be applied in the TCA technique.

Curved canal management

Based on canal curvature, Nagy et al. classified root canals into four categories:
1. straight or I-shaped (28 % of root canals);
2. apically curved or J-shaped (23 %);
3. entirely curved or C-shaped (33 %); and
4. multi-curved or S-shaped canals (16 %).

Schäfer et al. found that 84 % of root canals studied were curved, while 17.5 % of them presented a second curvature and were classified as S-shaped. Of all the curved canals studied, 75 % had a curvature of less than 27°, 10 % a curvature with an angle between 27 and 35°, and 15 % a severe curvature of more than 35°.

Traditionally, root canal curvatures were described using the Schneider angle: root canals presenting an angle of 5° or less were classified as straight canals, root canals...
with an angle of between 10 and 20° as moderately curved and canals with a curve of greater than 25° as severely curved. Decades later, Pruett et al. reported that two curved root canals might have the same Weine angle, but totally different abruptness of curvature. In order to define the abruptness, they introduced the radius of a curvature: the radius of a circle passing through the curved part. In rotary instruments, the number of cycles before failure significantly decreases as the radius of curvature decreases and the angle of curvature increases.

Further attempts to mathematically describe curvatures in 2D radiographs introduced parameters such as the length of the curved part and the location as defined by curvature height and distance. Recently, Estrela et al. described a method for determining the radius of root canal curvatures using CBCT images analysed by specific software. Three categories were classified: small ($r \leq 4$ mm), intermediate ($4 < r \leq 8$ mm) and large ($r > 8$ mm). The smaller the radius of a curvature is, the more abrupt the curvature becomes. All these attempts to describe the root canal curvature had one goal: to preoperatively assess the risk of transportation and unexpected instrument separation.

**Canal transportation and instrument separation**

According to the *Glossary of Endodontic Terms*, “transportation” is defined as the removal of the canal wall structure on the outside curve in the apical half owing to the tendency of files to restore themselves to their original linear shape. For stainless-steel hand files and conventional hand- or engine-driven NiTi files, the restoring force of a given instrument is directly related to its size and taper. The larger the size or taper, the larger the restoring force, owing to the increase of the metal mass of the instrument. If instruments were constructed precisely on the dimensions of root canals, transportation would not be a problem: instruments would be well constrained inside the root canal trajectories. Unfortunately, instruments are not precisely shaped to fit canal dimensions. As a result, each instrument may follow its own trajectory inside a curved canal guided by its restoring force, thus transporting the canal.

Usually, dentinal removal towards the outer apical curve becomes more excessive if a greater increase in apical enlargement is attempted to be created. Consequently, the inner curvature widening can become excessive too. To avoid these complications, dentists sometimes tend to increase flaring and reduce apical instrumentation size in severe curves. Increasing flaring under such circumstances often results in the reduction of the angle of curvature, shortening the length, increasing the radius and relocating the curvature apically (Fig. 2). Smaller apical preparations in highly curved canals would be preferable for two reasons: (a) smaller-diameter preparations are related to less cutting of the canal walls, less file engagement and, consequently, a lesser likelihood of undesirable cutting effects; and (b) small-diameter files are more flexible and fatigue-resistant and therefore less likely to cause transportation during enlargement.

The aforementioned instrumentation approaches, although safer, have inherent disadvantages. Unfortunately, flaring the canal entrance in order to achieve easier negotiation to the apical third of curved canals will result in unnecessary removal of dentinal structure that is irreplaceable. Moreover, smaller apical preparations may result in increased difficulties in delivering irrigating solutions to an appropriate depth. In highly curved canals, the ability of irrigating solutions to reach the critical apical third depends directly on the ability to create adequate apical preparations and the selection of appropriate delivery techniques. Adequate apical preparation for disinfection without over-flaring the coronal part of highly curved canals is one of the great challenges in endodontics—especially according to the current concepts of dentinal preservation and minimally invasive dentistry.

Moreover, the risk of unexpected instrument separation of engine-driven NiTi files poses significant problems to canal management. Two mechanisms have been identified: cyclic fatigue and torsional failure. When an engine-driven instrument is activated inside a curved canal, continuous tensile and compressive stress at the fulcrum of the curvature may lead to instrument separation because of cyclic fatigue. If the tip of an engine-driven instrument is locked inside a canal and the shaft keeps on moving, it may exceed an applied shear moment, resulting in torsional failure. As the complexity of the curvature increases, the number of cycles before failure decreases.
Using controlled memory files

NiTi alloys are overall softer than stainless steel, have a low elasticity (about one-fourth to one-fifth that of stainless steel) but greater strength, are tougher and more resilient, and show shape memory and super-elasticity. The NiTi alloys used in root canal therapy contain approximately 56% nickel and 44% titanium. They can exist in two different temperature-dependent crystal structures called martensite (low-temperature phase) and austenite (high-temperature phase). The lattice organisation can be transformed from austenitic to martensitic by adjusting temperature and stress. During the reverse transformation, the alloy goes through an unstable intermediate crystallographic phase called R-phase.

Root canal therapy causes stress to NiTi files: a stress-induced martensitic transformation of conventional NiTi files takes place instantly. A change in shape occurs with volume and density changes. This ability to resist stress without permanent deformation is called super-elasticity. The super-elasticity is most pronounced at the beginning, when a first deformation of as much as 8% strain can be totally overcome. After 100 deformations, the tolerance is about 6%, and after 100,000 deformations, it is about 4%. Within this range, the memory effect can be observed.

Besides stress-induced martensitic transformation, the lattice organisation of NiTi alloys can be altered by altering the temperature. When a conventional NiTi austenitic microstructure is cooled, it begins to change into martensite. The temperature at which this phenomenon begins is called the austenite start temperature. At and above the austenite finish temperature (A_1), the material will have completed its shape memory transformation and will display its super-elastic characteristics.

Before 2011, the A_1 temperature for the majority of available NiTi instruments was at or below room temperature. As a result, conventional NiTi files were in the austenitic phase during clinical use, showing shape memory and super-elasticity. In 2011, controlled memory (CM) files were introduced by international dental specialist COLTENE. These files are manufactured utilising a unique thermomechanical process that controls the material’s memory, making the files extremely flexible and fatigue-resistant without the shape memory and restoring force of other NiTi files. The A_1 transformation temperature of CM files has been found to be clearly above body temperature. As a result, these files are mainly in the martensitic phase at body temperature. When the material is in its martensitic form, it is soft, ductile and without shape memory, and can easily be deformed, but will recover its shape and super-elastic properties upon heating over the A_1 temperature. Moreover, a hybrid martensitic microstructure, like that used in the HyFlex CM files (COLTENE), is more likely to have a better fatigue resistance than an austenitic microstructure is. At the same stress intensity, the fatigue crack propagation speed of austenitic structures is much faster than that of martensitic ones. A quantitative analysis based on the model of the fracture process zone showed that the martensite transformation in the shape memory NiTi alloy caused a 47% increase in the apparent fracture toughness.
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Very recently, CM thermomechanical processing was combined with an innovative machining procedure for the manufacture of rotary NiTi files. Electrical discharge machining (EDM) results in instruments of increased surface hardness, cutting efficiency and extreme fatigue resistance. In the first published paper evaluating these files, a typical spark-machined peculiar surface was reported and low degradation was observed after multiple canal instrumentations.\(^{20}\) The authors also found surprisingly high values of cyclic fatigue resistance and safe in vitro use in severely curved canals. In agreement with previous researchers, Pedulla et al. reported higher values of fatigue resistance for HyFlex EDM files (COLTENE) even when compared with reciprocating files made from M-wire.\(^{21}\)

Unfortunately, most of the available literature on bending stiffness and cyclic fatigue fracture resistance of NiTi rotary or reciprocating instruments concerns studies performed at room temperature. However, room temperature is not a clinically relevant temperature. Current instruments are used at body temperature rather than room temperature. This makes most of the previous studies obsolete and their conclusions cannot be applied in the clinical practice. It seems that the transformation temperature (\(A_f\)) of rotary or reciprocating NiTi files might alter their clinical behaviour at body temperature. Hulsmann et al. (2019) reported that environment temperature has a 500% impact on the lifetime of instruments.\(^{22}\) A transformation temperature near body temperature can result in instruments that appear to be flexible and fatigue-resistant at room temperature; however, at clinically relevant temperatures, the instruments become stiffer and less fatigue-resistant. The \(A_f\) of HyFlex EDM was found to be close to 52°C, far above body temperature. \(A_f\) temperature analysis of EDM files revealed the presence of monoclinic martensite B19 structure and rhombohedral R-phase.\(^{23}\) Therefore...
EDM instruments are always in a rhombohedral R-phase and martensitic crystallographic state at clinically relevant temperatures. A martensitic structure at body temperature, like HyFlex EDM, will exert superior flexibility and fatigue fracture resistance. The extreme flexibility and fatigue resistance of these files, combined with the lack of restoring force, render them ideal for use in the instrumentation of highly curved and complicated canals.

**HyFlex EDM Max Curve sequence**

EDM made feasible the use of a single-file enlargement approach with rotational movement. Most cases can be shaped quite quickly, effectively and safely by using a single 25/- HyFlex EDM OneFile with short-stroke pecking movements, frequent flute cleaning and irrigation between the strokes. The OneFile has a tip size of 25 with a .08 taper. The taper is a constant .08 in the apical 4 mm of the instruments, but reduces progressively up to .04 in the coronal portion of the instrument. The file has three different cross-sectional zones over the entire length of the working part (rectangular in the apical part and two different trapezoidal cross sections in the middle and coronal parts of the instrument) to increase its fracture resistance and cutting efficiency. Whenever larger apical preparations are required, three finishing HyFlex EDM files of constant taper can be used (40/.04, 50/.03 and 60/.02).

For constricted and obliterated canals, thin and long roots, curved canals of more than 27° and S-shaped canals with a curvature of smaller than 5 mm in radius, single-file EDM shaping is not feasible. For these challenging cases, the HyFlex EDM Max Curve sequence was introduced for use with the TCA technique. With this combination, all those cases can be handled effectively and predictably. The new
HyFlex EDM Max Curve set includes 15/.03, 10/.05 and 20/.05 files. Under the new concepts of dentinal preservation, flaring can be avoided in order to reduce unnecessary tissue removal from the peri-cervical area. The HyFlex EDM Max Curve sequence can be used with a single-stroke TCA technique. After canal identification and negation, a minimum glide path of 10/.02 should be achieved with stainless-steel hand files before moving to the Max Curve rotary sequence. After making the 10/.02 hand file super loose, the 15/.03 HyFlex EDM file is used to shift the manually achieved glide path to a smooth glide path that all subsequent rotary files can follow. After the 15/.03 file has reached the predetermined length, the 10/.05 HyFlex EDM follows in order to enlarge the middle part of the canal safely without binding the delicate tip. The apical 3 mm of the 10/.05 file functions as a guiding tip (without engaging the canal walls, Fig. 3). The 20/.05 HyFlex EDM file follows as a finishing file to give the final smooth shape. Once a 20/.05 enlargement has been achieved, the canal can be filled with a 20/.05 gutta-percha cone and GuttaFlow bioseal bioceramic sealer (COLTEN). The sequence is easy to remember and works effectively and safely even in tricky situations.

**Tactile-controlled activation**

To minimise file engagement, TCA was developed (Fig. 4a). This instrumentation technique can be defined as the activation of a motionless engine-driven file only after it becomes fully engaged inside a patent canal. TCA utilises file activation only after maximum engagement of the flutes is reached and tactile feedback of the anatomy is felt. Inserting files passively (non-activated) inside the root canals and using CM files that can be pre-bent before file insertion is useful, especially when complicated canal systems are encountered and limited mouth opening hinders canal negotiation and visualisation. TCA can be divided into in-stroke and out-stroke movements. After accessing the pulp chamber and locating the canal orifices, technical patency to length is confirmed and the canal is enlarged up to 10/.02. The first file of the Max Curve sequence to be used, the 15/.03 file, is mounted on to the handpiece of an endodontic motor and inserted passively inside the canal to the point of maximum frictional resistance (point A, Fig. 4b). The file is activated and pushed apically (in-stroke) until the activated file resists further advancement (point B, Fig. 4c) and withdrawn from the canal. After file withdrawal, the file is inactivated and the flutes are cleaned and checked for any possible deformations. Irrigation and patency confirmation follow. The second time that the same file is inserted passively inside the canal it will bind deeper inside the anatomy (point B, Fig. 4d). Activating the file again the same way will guide the file even closer apically to length (point C, Figs. 4e–g). The work to be done by this file is completed when the file can reach working length (point D, Fig. 4h) without having to activate it. After reaching working length, the second file...
of the Max Curve set is used the same way. The delicate apical 2 mm of the 10/.05 file will always remain loose inside the canal, guiding the file through the anatomy without risking engagement and breakage. The 20/.05 that follows will provide the final canal shape to disinfect and obturate the canal.

Instrumentation to larger apical preparations can be achieved the same way to the desired apical instrumentation width. For challenging cases, as seen in Figures 5 and 6, a 20/.05 enlargement might be ideal in order to balance the clinical disinfection procedures with the risks of damaging the challenging anatomy or separating the instruments. The TCA technique aims at minimising the time of engagement with an activated file by using file activation only when needed for advancement. With this instrumentation technique and the HyFlex EDM Max Curve sequence, most anatomical root canal variations can be enlarged safely.

**Conclusion**

NiTi files with CM effect are extremely flexible and fatigue-resistant. They can be activated inside the canal and move passively around the curves guided only by anatomy itself. The TCA technique minimises the time files are under engagement. This procedure maintains continuous tactile feedback during instrumentation. For challenging anatomies, special sequences like the HyFlex EDM Max Curve set help clinicians to keep on track.

**about**

Dr Antonis Chaniotis graduated from the University of Athens’s School of Dentistry in Greece in 1998. In 2003, he completed a three-year postgraduate programme in endodontics at the same school. Since 2003, he has owned a private practice limited to microscopic endodontics in Athens. For the last ten years, he has served as a clinical instructor affiliated with the undergraduate and postgraduate programmes at the Department of Endodontics of the University of Athens’s School of Dentistry. From 2012 to 2014, he was a clinical fellow teacher at the University of Warwick in the UK. He lectures extensively nationally and internationally, and he has published articles in local and international journals. He currently serves as an active member of the Hellenic Society of Endodontology, a certified member of the European Society of Endodontology, and an international member of the American Association of Endodontists.

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Clinical applications of mineral trioxide aggregate in endodontics

Drs Arnaldo Castellucci, Matteo Papaleoni & Francesca Cerutti, Italy

Bioceramic-based sealers are ceramic products that are designed for medical and dental applications and include alumina, zirconia, bioactive glass, glass-ceramics, hydroxyapatite and calcium phosphates. Bioceramic-based sealers are categorised into two groups: calcium silicate-based sealers and calcium phosphate-based sealers. Also, these materials can be considered bioactive or bio-inert according to their interaction with the surrounding live tissue.

Calcium silicate-based sealers are either based on mineral trioxide aggregate (MTA) or non-MTA-based. MTA is a bioactive material first introduced to seal communication between roots and external surfaces of teeth. It promotes osteogenesis and healing, allowing clinicians to perform therapies that would not previously have been successful (Figs. 1–4). The first formulation of MTA (grey) was composed of silicate, bismuth oxide, tricalcium aluminate, calcium sulphate dihydrate (gypsum) and calcium aluminoferrite. The subsequent version (white) is composed of tricalcium silicate, dicalcium silicate, bismuth oxide, tricalcium aluminate, calcium oxide, aluminium oxide and silicon dioxide. The powder has to be mixed with distilled water to be used. The initial setting time ranges from 8 to 70 minutes, and the final setting time ranges from 40 to 320 minutes. This long setting time is one of the main drawbacks of this product.

The material has peculiar features, such as excellent biocompatibility and sealing ability, even in the presence of...
moisture. It has a hydrophilic nature and good capacity for marginal adaptation, together with good antibacterial properties (thanks to its high pH of 12.5), and it is able to stimulate cementum-like formation, osteoblastic adherence and bone regeneration. Moreover, its sealing, mineralising, dentinogenic and osteogenic potentials make it the preferred choice for numerous clinical applications, such as direct pulp capping, root end filling, apexogenesis and apicalisation in immature teeth with necrotic pulp, filling of root canals, treatment of horizontal root fractures, treatment of internal and external resorption, and repair of perforations.5

The literature reports good outcomes in perforation repair using MTA with respect to a variety of materials used to fill endodontic perforations, such as amalgam, zinc oxide eugenol cements, calcium hydroxide, composite resin and glass ionomer cements.6 The outcome of the therapy has been found to be influenced by the experience of the practitioner who performed the treatment, the negative influence of placing a post after treatment, the presence of preoperative lesions and of communication between the perforation site and oral cavity, and the sex (female) of the patient.7,8 The location of the perforation and the quality of the final restoration have been found to have a significant influence on the outcome of the perforation repair, while the site of perforation (mid-root and apical) and a perforation size of larger than 3 mm have been reported as significant predictors of the recurrence of progressive inflammation.7

When apical surgery is performed, the choice of the root end filling material can have a significant influence on the outcome of the therapy. Amalgam has been the most popular root end filling material for a long time, but it has been demonstrated that its use is related to an increase of blood mercury levels within one week of the procedure.8 Moreover, the sealing ability of amalgam does not ensure good results over time when used in apical surgery. Since MTA has been introduced, it has become the gold standard for this procedure because of its excellent sealing ability, hard-tissue induction and conduction, and success rate over time.5 The literature shows that MTA presents similar or better outcomes in terms of regeneration of periapical tissue compared with SuperEBA (Keystone Industries), amalgam, Intermediate Restorative Material (Dentsply Sirona), 4-META/MMA-TBB resin and thermo-plasticised gutta-percha.9,10

The excellent biocompatibility of MTA makes it the material of choice for filling the apices of large root canals and for apexification/apexogenesis in immature teeth with necrotic pulp. For this latter procedure, in fact, the contact between MTA and periapical tissue promotes the formation of hard tissue and promotes the survival of the tooth over time (Fig. 5).11,12 MTA is also used in the therapy of vital pulp, such as pulp revitalisation and pulp capping, taking the place of calcium hydroxide as the material with the best performance and the fewest side effects (Fig. 6).13,14

Several investigations evaluated other bioactive endodontic cements (BECs) as pulp capping agents with short-term follow-up. More research with longer-term follow-up is needed to evaluate alternative pulp capping materials to MTA. In addition to the material used for direct pulp capping, there are several other factors that may influence the final outcome; therefore, these variables should be controlled in future studies.14

The literature has reported some disadvantages related to the composition of MTA. The presence of bismuth oxide as a radiopacifier in the MTA formula has been proved by several studies to potentially lead to tooth discoloration, both via bismuth changing from its oxide form to metal by reduction, resulting in a black compound and subsequent tooth staining, or via bismuth undergoing oxidation when in contact with a strong oxidising agent (i.e. sodium hypochlorite), producing bismuth carbonate, which results in a black precipitate when exposed to light.8

Since MTA’s discoloration potential has been stated as a main shortcoming in vital pulp therapy and in perforation repair (Fig. 7), alternative bioactive cements, with similar clinical applications and shorter setting times, were de-
Some of them had the same discoloration problem when in contact with sodium hypochlorite. Other formulations, containing tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium oxide and tungstate as an opacifier (i.e. PD MTA White, Produits Dentaires), reached the goal of avoiding staining and discoloration without changing the biological or chemical features of MTA.

One of the major problems when using MTA in vital teeth is bleeding management. Several studies have reported blood contamination as a factor that exacerbates discoloration in calcium silicate-based materials; bismuth oxide-free Portland cement also presents colour alteration subsequent to blood exposure. The hypothesis of unset MTA presenting surface porosities that take up blood elements has been proposed to explain the discoloration of calcium silicate-based cements, as erythrocytes can penetrate into the material, and after their haemolysis, both the cement and the tooth could present discoloration. Another suggested mechanism for tooth discoloration after MTA placement may be the oxidation and incorporation of the remaining iron content into the set material: contact with blood triggers loss of the ferrous ion (Fe$^{2+}$) contained within the centre of the porphyrin ring through a natural redox reaction that originates Fe$^{3+}$, a dark brown component that promotes material and tooth discoloration. Furthermore, the penetration of blood into the tooth structure, with haemoglobin or haematin molecules present within the dentinal tubules, may induce discoloration. In this regard, the release of fast-setting MTA can represent a significant advantage, limiting fluid and blood absorption and thereby preventing discoloration and promoting a pleasant aesthetic outcome. White MTA is good from this point of view because it starts setting after 10 minutes and setting is completed after 15 minutes. While setting, the material does not shrink, and after setting, it is dimensionally stable, ensuring a tight seal over time. The fast setting also allows performance of the restorative procedures in the same appointment in which the MTA is placed, improving the workflow of the practitioner.

Other bioactive endodontic materials that contain ZrO$_2$ to provide radiopacity and guarantee superior colour stability have been suggested in order to overcome MTA-related problems. The literature reports that some BECs have shown promising results, above all in vital pulp therapy, in terms of cementum deposition over the materials when used for root end filling, while others are associated with a significantly higher inflammation of the periapical tissue compared with tooth-coloured MTA. However, the number of studies comparing these products to MTA is still limited and few histological investigations have evaluated BECs as root end filling materials. Their shortcomings include short-term follow-up, absence of controls, a large number of excluded specimens, placement of root end filling materials in intact
teeth with healthy pulps that had no periapical lesions prior to treatment, preparing root end cavities without prior canal debridement and filling, and root resection and preparation of root end cavities prior to root canal instrumentation.\(^8,16\) Future investigations with rigorous methods and materials are needed to exactly compare the performance of these materials.

The literature reports more potential drawbacks of MTA, such as the difficult handling.\(^16\) It has to be said that, if the practitioner follows the instructions provided by the manufacturer, mixing MTA is straightforward. It is sufficient to place the contents of one sachet of MTA on to a glass slab and add one drop of distilled water next to the powder. Mixing has to be carried out gradually, bringing the liquid into the powder and mixing it evenly for 30 seconds, until the mixture shows a creamy consistency. Once mixed, it is important to position the material precisely into the site that has to be filled. This step can be tricky if no specific carrier is available. A number of dedicated carriers are available on the market. These are of different sizes, according to the amount of material to be placed and to the area of the root canal to be reached. Carriers should allow fast, efficient and precise positioning of the material. This implicates the possibility of delivering the material into the carrier effortlessly, bending the tip and delivering the desired amount of MTA to the target site.

The MAP system (Produits Dentaires) is a dedicated carrier that was developed to adapt to every clinical situation, because it can be used with tips of different sizes and angles and with different materials. In general, triple-angled stainless-steel tips are used in endodontic surgery, because they improve the visibility of the operative field and make retrograde obturation easier. The classic curved stainless-steel tips are meant to be used in or-

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**Figs. 6a–g:** Pre-op radiograph of the maxillary right first molar, showing deep decay involving the pulp tissue (a). The image shows the exposed pulp (b). PD MTA White positioned over the exposed pulp (c). After setting, the cavity was restored in the same visit (d). Clinical aspect of the restoration (e). Post-op radiograph (f). One-year recall radiograph (g).

**Figs. 7a–e:** Pre-op radiograph of the maxillary right central incisor. The tooth had a buccal perforation in the middle third of the root (a). The granulation tissue was occupying part of the pulp chamber (b). After removing the granulation tissue, the perforation was sealed with white MTA (c). Post-op radiograph (d). Three-year recall radiograph (e).
orthograde treatments or pretreatments, in order to perform direct pulp capping, root canal obturation during apexogenesis and revascularisation procedures, apexification of immature teeth and repair of root canal perforations. The advantage of the MAP System is the possibility of employing nickel-titanium tips. These can be used in both orthograde and surgical procedures and allow placement of the material exactly where it is needed because they can be bent as necessary (Fig. 9). After sterilisation, the tips resume their initial straight shape (Fig. 10).

When using an MTA carrier, it is mandatory to avoid the material hardening inside of the applicator, because it may be almost impossible to remove it afterwards. Cleaning the tip (better done with dedicated tools) immediately after MTA extrusion helps maintain the efficiency of the instrument.

The amount of MTA to be used is dependent on the clinical procedure, but in general, it is not recommended to completely fill a root canal with MTA, because it would be difficult to remove the material from the root canal after setting. A rigorous protocol and the use of specific tools help achieve good outcomes in primary and secondary endodontic treatments using MTA as an obturation material.

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

Since 1980, Dr Arnaldo Castellucci has limited his activity as a dental specialist to the sole specialty of endodontics. Thanks to the rich clinical experience he acquired through the instruction he received while attending the Department of Endodontics, then under the chairmanship of Prof. Herbert Schilder, at Boston University School of Graduate Dentistry (now the Boston University Henry M. Goldman School of Dental Medicine) in the USA, he was able to successfully pursue intense educational activity, as well as present lectures at both national and international congresses, becoming one of today’s most cited endodontists worldwide. In his dental practice, Dr Castellucci offers his patients the maximum clinical professionalism and the best specialisation to treat endodontic pathology with the most recent clinical and surgical technology. Furthermore, thanks to the highly equipped didactic environment that Dr Castellucci has set up over the years in his practice, he is able to convey his experience with the maximum effectiveness to all those dental professionals pursuing specialisation in endodontics through educational courses that he personally organises and presents.

Dr Matteo Papaleoni graduated from the University of Florence in Italy in 2004. He received his master’s degree in endodontics and restorative dentistry from the University of Siena in Italy in 2006. Since 2008, he has collaborated with Dr Castellucci, particularly regarding aesthetic dentistry and tooth restoration with minimally invasive techniques. He is currently a presenter in Dr Castellucci’s annual course on the restoration of the endodontically treated tooth. Dr Papaleoni has contributed to numerous scientific publications on endodontics and is a member of the Italian Society of Endodontics.

Dr Francesca Cerutti graduated from the University of Brescia in Italy in 2007. In 2013, she obtained her PhD in materials for engineering from the University of Brescia, and in 2016, she completed a master’s degree in aesthetic medicine. She collaborates with Prof. Dino Re at the University of Milan in Italy, where she conducts clinical research and, since 2018, has been a visiting professor. Dr Cerutti has published several articles in peer-reviewed journals and has co-authored books on restorative dentistry and endodontics. Dr Cerutti has spoken at national and international congresses on postendodontic restoration and aesthetic reconstruction of teeth. She is a reviewer for international journals such as the Journal of Adhesive Dentistry, the European Journal of Paediatric Dentistry and Biomaterials. Dr Cerutti is a member of the Italian Society of Endodontics and served as editorial coordinator of Giornale Italiano di Endodonzia from 2008 to 2011. She is a silver member of Style Italiano Endodontics.
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Effect of duration of Er, Cr:YSGG laser etching on dentine morphology

An in vitro study

Drs Farnaz Mahdisiar, Alireza Mirzaei, Alireza Fallah, Saeedeh Akhoundan, Iran &
Prof. Nobert Gutknecht, Germany

The conventional method of cavity preparation by rotary instruments is not favoured by many patients. On the other hand, dentine prepared as such is covered with smear layer, which is composed of dental hard tissue, carious debris, and residual bacteria. This decreases the dentine surface energy and prevents adequate adhesion to dentine. Dentine is a major component of teeth. It is a complex substrate for bonding due to its heterogeneous composition, mainly organic structure, hydrophilic nature, and morphological variations. Introduction of adhesive primers with enhanced hydrophilicity for dentine surface conditioning and providing a stronger bond to more hydrophobic adhesive resins largely resolved this issue. The conventional method of forming a strong bond to dentine is via phosphoric acid etching and removal of the mineral content to create microporosities within the collagen network. Upon removal of the hydroxyapatite crystals of the outer layer of dentine, about 50 % unfilled space and about 20 % of water remain in the dentine surface. In order to obtain a strong bond, resin should infiltrate into the collagen scaffold and form a hybrid layer. The primer also penetrates into the dentinal tubules concurrent with the formation of the hybrid layer. This results in formation of quite large resin tags. After etching, the tooth should be rinsed with air and water spray to thoroughly remove the acid and stop the etching process. Otherwise, cysteine cathepsins, which can be activated in mildly acidic environments, may also activate matrix-bound matrix metalloproteinases and destabilise the hybrid layer in long term. If the etching time is too long and the etched zone is too deep, decalcified dentine may not be fully impregnated. The etched but not impregnated space may serve as a mechanically weak zone.

After rinsing, drying of dentine must be performed cautiously. Even a short air blast from an air–water spray can inadvertently dehydrate the outer surface and cause the remaining collagen scaffold to collapse. Once it happens, the collagen mesh prevents the penetration of primer and bonding will fail. On the other hand, excess moisture tends to dilute the primer and interfere with resin penetration. Excessive acid conditioning causes incomplete infiltration of resin monomers and creates a gap between resin tags and dental structure that decreases the bond strength by creating a weak zone. In conventional surface treatment, the primer penetrates into the fluid-filled dentinal tubules. It is generally under-cured and forms soft flexible tags.

Today, laser system, as a novel modality, has been suggested for use as an alternative to dentine surface etching. Among laser systems, the erbium family of lasers is believed to be the most successful. There are several studies that have explored various parameters such as laser power and frequency for dentine etching and surface conditioning for proper bonding. But no study has investigated the effects of duration of Er, Cr:YSGG laser etching on dentine surface morphology. The aim of this study was to evaluate ultrastructural morphological changes in dentine following different durations of Er, Cr:YSGG laser irradiation using scanning electron microscopy (SEM).

Materials and methods

Sample preparation
Twenty-five extracted human-impacted permanent third molars were used in this study. Soft tissue residues were completely removed from the tooth surfaces with a dental scaler. All teeth were then stored in distilled water.

<table>
<thead>
<tr>
<th>Duration of irradiation</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T0 = control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Exposure 2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Exposure 3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Exposure 4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Exposure 5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

0 = smear layer was not observed
1 = smear layer was observed
T1–T4 = different durations of irradiation: T1, 5 s; T2, 10 s; T3, 20 s; T4, 40 s; T0, no irradiation
Exposure 1–5 = number of irradiated areas by Er, Cr:YSGG laser

Table 1: Effect of duration of irradiation on the smear layer.
containing 0.4% thymol for one week for disinfection. Then, samples were stored in distilled water at room temperature until the experiment. Each tooth was cut below the occlusal pit and fissure level, perpendicular to the longitudinal axis of the tooth by means of a high-speed handpiece and silicon carbide disc to remove the occlusal enamel and expose the superficial dentine surface. Next, an area measuring 5 mm in length and 5 mm in width was prepared on the occlusal surface of each tooth for laser irradiation.

**Laser application**

The marked occlusal area was irradiated with Er,Cr:YSGG laser (BIOLASE) at a wavelength of 2,780 nm. The laser parameters were as follows: Output power 4.5 W, peak power 1,500 W, energy density per pulse 8.57 J/cm², energy per pulse 0.09 J, frequency 50 Hz, water 80, air 60, pulse duration 60 µs, tip diameter 600 µm, cross section of tip 0.028 cm², angle of radiation 8, irradiation surface 1.16 mm, distance 2 mm. The teeth were randomly divided into five groups according to the duration of laser irradiation: T1, 5 s; T2, 10 s; T3, 20 s; T4, 40 s; T0, no laser irradiation. After laser irradiation, the samples were stored in distilled water.

**SEM analysis**

The effects of laser irradiation on dentine surfaces were evaluated using SEM at 80x and 500x magnifications. Prior to SEM analysis, the samples were vacuum-dried and sputter-coated with gold for 180 s. SEM observations were carried out at an accelerated voltage of 20 kV with 25 mm working distance. SEM findings were scored to evaluate the effect of duration of laser irradiation on the smear layer as follows: Score 0 = absence of smear layer; Score 1 = presence of smear layer. More SEM images were obtained from sample number 4 at 1.00 kx, 3.00 kx, 5.00 kx, 10.00 kx, and 20.00 kx magnifications.

**Figs. 1a & b:** SEM micrographs of the dentine surfaces pre-treated only with silicon disc (control group). a 80x. b 500x. **Figs. 2a & b:** SEM micrographs of the dentine surfaces pre-treated with Er,Cr:YSGG laser irradiation for 5 s. a 80x. b 500x. **Figs. 3a & b:** SEM micrographs of the dentine surfaces pre-treated with Er,Cr:YSGG laser irradiation for 10 s. a 80x. b 500x. **Figs. 4a & b:** SEM micrographs of the dentine surfaces pre-treated with Er,Cr:YSGG laser irradiation for 20 s. a 80x. b 500x.
Results

Analysis of the results with the Mann–Whitney U test showed that 40 s of irradiation in T4 group caused significant removal of the smear layer compared to T0 group (P = 0.008). Other durations of radiation did not completely remove the smear layer (P = 1, Table 1). SEM morphological analysis of the specimens showed different characteristics according to the surface pretreatment, as described below: Control group (T0): The surface was covered with smear layer (Fig. 1). Er,Cr:YSGG laser irradiation for 5, 10, and 20 s: The dentine surface in these groups revealed different amounts of the smear layer (Figs. 2–4). Er,Cr:YSGG laser irradiation for 40 s: Dentine surface in this group showed an irregular pattern without the smear layer, with open dentinal tubules and no enlargement. A prominent peritubular dentine appearance suggested greater removal of intertubular dentine due to its higher water sorption. There were no evident signs of melting or microcracks (Fig. 5). Among the different time durations of Er,Cr:YSGG laser irradiation, only 40 s of laser irradiation caused smear layer removal from the dentinal tubules. According to the results in group 4, further SEM analyses at 80kx, 500kx, 1000kx, 3000kx, 5000kx, 10000kx, and 20000kx magnifications were performed in this group (Fig. 6).

Discussion

The quality of the dentine-resin interface plays an important role in achieving a high quality and durable composite restoration. Dentine preparation by rotary instruments creates smear layer on dentine surface that causes problems in obtaining suitable bond between the adhesives and dentine. On the other hand, the conventional method of smear layer removal includes the use of phosphoric acid on dentine for 15 s. This method has limitations such as (1) demineralisation that occurs with the removal of dentine mineral content, (2) over-etching since by increasing the duration of etching, greater depth of dentine is demineralised, (3) inadequate washing of the etchant results in unwanted continuation of the etching process, and (4) over-drying causes the collagen network to collapse and under-drying dilutes the primer. After the application of bonding agent, resin tags form by penetration of
primer into the fluid-filled dentinal tubules. These resin
tags are generally under-cured, soft, and flexible. In ad-
dition, the interface is prone to nano-leakage because of
gap formation between tags and dentine due to incom-
plete penetration of adhesive.5,7

In the 1990s, erbium lasers were introduced for prepara-
tion of hard tissue as an alternative to rotary instruments.
Er,Cr:YSGG laser (emitting at a wavelength of 2.79 µm) is
an effective tool for removal of dental hard tissues.14,15
This wavelength is absorbed by the hydroxyapatite and
water. The hydroxyl radicals and water in hydroxyapatite
crystals receive most of the laser energy. By water evapo-
rations in the tooth mineral components, a large volumetric
expansion occurs.1,2 Next, micro-explosions occur that
remove the hard tissue from the irradiated regions.16 It has
minimal side effects on the sound tooth structure.2 Den-
tine conditioning with laser has advantages. As reported in
some studies, the laser settings can be adjusted to physi-
cally etch the dentine surface. Power, frequency, and other
parameters can be adjusted to prevent smear layer for-
mination on the dentine surface. Laser does not cause den-
tine demineralisation. It does not have the risk of over-etch-
ing or over-/under-drying. The erbium laser-treated dentine
is dehydrated prior to priming and bonding; thus, the
resin tags are more likely to be long and strong.1,7,18 Of
studies on the effect of different laser parameters on
dentine morphology, no study investigated the effect of
various durations of Er,Cr:YSGG laser irradiation on den-
tine surface morphology. Dentine irradiated with Er,Cr:YSGG
laser shows a microscopically rough surface without de-
mineralisation,19,20 open dentinal tubules,21–23 no smear
layer, and satisfactory sterilisation of the cavity.24 These
characteristics are considered as an advantage of laser
preparation if composite resins are to be applied as the fill-
ing materials.25

The Er,Cr:YSGG laser setting used in this study included
4.5 W average power, 1,500 W peak power, 0.09 J energy
per pulse, 50 Hz frequency, 8.57 J/cm² energy density,
80% water and 60% air, pulse duration of 60 µs, and
distance of 2 mm above the surface. The energy density
used in our study was not within the ablation range. Only
dentine surface was etched and conditioned for the bond-
ing process. Five, 10, and 20 s of laser irradiation caused
different amounts of smear layer. The applied Er,Cr:YSGG
laser setting with 40 s of duration caused a scaly-like
appearance on the surface with less homogenous and
less regular surface creating a micro-retentive pattern on
dentine without heat injury or melting, which is favour-
able for bonding process. The dentine surface showed
no smear layer; dentinal tubules were open; and the sub-
surface was not demineralised. Open tubules and ab-
sence of smear layer are additional factors that enhance
bonding to laser-treated dentine.14 This can be explained
by micro-explosions at the tissue surface, resulting from
the sudden boiling of water within the tissue (thermo-
mechanical ablation).26 The results obtained from this
study can be used in further studies to evaluate the com-
posite bond strength with different bonding systems.

Conclusion

Forty seconds of laser irradiation with the aforemen-
tioned parameters eliminated the smear layer from the
dentine surface, and the obtained surface had micro-
retentive pattern on dentine and open tubules without
heat injury or melting and demineralisation which was
suitable morphology for bond to composite resin. Laser
irradiation for less than 40 s could not completely remove
the smear layer from the surface. Each one of these sur-
faces could have optimum bonding with composite by
applying different adhesives systems which should be
investigated in further studies.

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interest. In addition, this article does not contain any
studies with human participants or animals performed
by any of the authors. This article was done on extracted
human third molars, and it does not include any human
participant. For this type of study, formal consent is not
required.

about

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SSP/SWEEPS endodontics with the SkyPulse Er:YAG laser

Dr Tomaž Ivanušič, Slovenia

Introduction

The goal of endodontic therapy is to eliminate pathogenic substances from the root canal system. However, standard mechanical instrumentation leaves a significant portion of the complex root canal system uninstrumented. Additionally, the mechanical instrumentation itself creates a smear layer and an accumulation of debris that need to be removed as well. For this reason, an irrigation phase of the therapy is required in order to eliminate the potential pathogens, and to remove the debris resulting from the instrumentation phase of the procedure. Different methods and technologies have been introduced with the goal to improve the efficacy of the standard syringe root canal irrigation procedure. One of the most recent techniques involves SSP/SWEEPS® laser-activated irrigation (LAI) using a special type of the Er:YAG (erbium-doped yttrium aluminium garnet) laser with extremely short laser pulses, generating photon-induced photoacoustic streaming of the irrigant throughout the complex three-dimensional root canal system (Fig. 1).

The photon-induced photoacoustic streaming is achieved through the high absorption of the SSP (super-short pulse; 50 µs) Er:YAG laser pulse in the irrigant, which initiates the rapid formation of a vapor bubble at the fibre tip (FT) while it is immersed in the irrigant. Due to the very high absorption coefficient of the Er:YAG laser wavelength (λ = 2,940 nm) in irrigants, all of the laser pulse light is absorbed within the approximately 1 µm-thick fluid layer. Thus, the fluid is locally and instantly heated over the boiling point and a vapor bubble starts to form at the FT’s end. After the explosive boiling, the vapor bubble starts to expand. When it reaches its maximum volume, it is nearly empty and it starts to collapse due to the pressure of the surrounding liquid. This phenomenon induces turbulent fluid movement within the whole root canal volume, significantly improving the efficacy of chemomechanical debridement. Additionally, for super-short laser pulses, the effects of thermal diffusion during bubble formation are minimal.

A unique solution for modern endodontics

The ultimate goal of SSP/SWEEPS® is to significantly enhance several irrigation mechanisms: 3D streaming of the irrigant throughout the complex root canal system; increased penetration of the irrigant deeper into the dentinal tubules; removal of debris and the smear layer from the root canal system; more effective chemical activation of NaOCl; direct (non-chemical) removal of biofilm; and direct (non-chemical) disinfection. The clinical efficacy and safety of SSP laser-activated irrigation has been extensively investigated. However, research indicates that further improvements can be achieved by tailoring the Er:YAG laser emission characteristics to the specific requirements of the above irrigation mechanism.

This has led to the development of SSP/SWEEPS® endodontics, where the extremely effective single-pulse SSP irrigation is complemented with an additional, dual-pulse SWEEPS® (shock wave enhanced emission photoacoustic streaming) technique. The SWEEPS® modality is based on the finding that, as opposed to large liquid reservoirs, shock waves, i.e. waves travelling faster than sound, are not observed in spatially confined reservoirs such as root canals. This is because in narrow canals cavitation dynamics are significantly slowed down by the friction on the canal walls and by
the limited space available for the quick displacement of the liquid during the bubble's expansion and contraction. The SWEEPS® modality consists of delivering a subsequent laser pulse into the liquid at an optimal time when the initial bubble is in the final phase of its collapse. The growth of the second bubble exerts pressure on the collapsing initial bubble, accelerating its collapse and the collapse of secondary bubbles, resulting in the emission of primary and also secondary shock waves.

Materials and methods

The Er:YAG laser (\(\lambda = 2,940\,\text{nm}\)) used in this study was the SkyPulse (Fotona), equipped with the H14 handpiece, optically coupled with interchangeable fibre tips (Fig. 2). The handpiece air/water spray was turned off during all experiments. The following fibre tips were used in the study:

1. Cylindrical flat-ended fibre tips with diameters of 400 \(\mu\text{m}\) (Flat Sweeps400) 500 \(\mu\text{m}\) (Flat Varian500) and 600 \(\mu\text{m}\) (Flat Varian600);*

2. Cylindrical radially-ended (tapered) tips with diameters of 400 \(\mu\text{m}\) (Radial Sweeps400) and 600 \(\mu\text{m}\) (Radial Sweeps600). Note that the Radial Sweeps600 tip is geometrically equivalent to the standard 600 \(\mu\text{m}\) “PIPS” fibre tip.*

3. Conical flat-ended tips with diameters of 400 \(\mu\text{m}\) (Conical Sapphire 400) and 600 \(\mu\text{m}\) (Conical Sapphire 600).

The SkyPulse laser system was operated in the single-pulse SSP emission mode and in the dual-pulse SWEEPS® emission mode. Since the proper timing of the SWEEPS® pulse pair depends on the cavitation bubble’s oscillation time, which depends on the geometry of the access chamber, the SkyPulse’s SWEEPS® modality consists of automatic repetitive sweeping of the temporal separation between the SWEEPS® pulse pair back and forth within an optimal range (SWEEPS®) of temporal separations in order to ensure effective irrigation regardless of the tooth type and chamber size preparation. It is the accelerated collapse of the first bubble in the SWEEPS® pulse pair that results in the enhanced shock wave emission and improved irrigation, while the role of the second bubble is mainly to amplify the effect of the first bubble.

Measurement of root canal pressure

Measurements were performed in a simulated tooth model with the entrance diameter of the conically shaped access cavity of 3 mm, submerged 4 mm deep under the water level of a large water-filled reservoir. This provided a stable fluid pressure within the root canal in the absence of LAI, and enabled constant replenishment of irrigant. The laser fibre tip’s end was positioned 2.5 mm deep into the access chamber. The average generated pressures \(P_{ave}\) for different irrigation protocols were calculated based on determining the pressure changes in apical, middle and coronal part of the simulated tooth model. The SkyPulse Er:YAG laser was set to emit radiation in the single pulse SSP emission mode. For comparison, measurements with another Er:YAG laser device, LightWalker (Fotona) were also made under the same conditions and using the same handpiece (H14) and fibre tips. Both lasers were operated with the single-pulse energy of 20 mJ and a repetition rate of 15 Hz.

Measurement of debris removal rate

Cleaning efficacy was measured in a root canal model. The experimental set-up consisted of a transparent root canal model, submerged in a glass container filled with distilled water. The root canal model was filled-up with a suspension paste to simulate debris. A biological calcium hydroxide-based paste was used in the validation phase of the experiment. In the measurement phase, a gel den-
Tifrice was used, which yielded comparable results to the biological paste but was easier to handle and required less time to empty and refill the root canal model between measurements.

Laser pulses with a single-pulse energy of 20 mJ were delivered through the Flat Sweeps400 fibre tip positioned inside the root canal model. The images of the root canal during LAI were captured by a video camera and analysed using custom-developed software. The cleaning rate was determined from the measured reduction of the height of the simulated debris (paste) within the root canal model, with the irrigation time of 180 s. Shorter irrigation times were used for calculation when the root canal became fully cleaned, i.e. emptied of the paste, already before the expiry of 180 s. Each cleaning rate data point represents an average of at least five repeated irrigations. The cleaning rate measurements were made for the single-pulse SSP emission mode and for the automatically swept SWEEPS® emission mode.

Results

Pressure measurements
Dependence of average pressures \( P_{ave} \) (as measured for both LightWalker and SkyPulse laser devices in SSP mode) on fibre tip type (radial, flat or conical) and diameter is shown in Figure 3. Pressure measurement results show that in general the pressure generation efficacy is higher for smaller fibre tip diameters. Detailed pressure distributions within the apical, medial and coronal part of the root canal, as measured with the SkyPulse in SSP mode, are presented in Figure 4. The distribution of irrigant pressures within the root canal as shown in Figure 4 are in agreement with the reported irrigant penetration depths at different root canal areas.

Cleaning rate measurements
The measured debris removal (i.e. cleaning) rates \( R_c \) for the SkyPulse SSP and SWEEPS® emission modes with single-pulse energy of 20 mJ are shown in Figure 5. The SWEEPS® mode was delivered at repetition rate of 20 Hz while the SSP emission mode was tested in the range of 15–50 Hz, in order to determine whether doubling the single-pulse repetition rate of the SSP mode would yield similar results as the dual-pulse SWEEPS® mode. As can be seen from Figure 5, the debris removal rate of the dual-pulse SWEEPS® mode is significantly higher in comparison to the single-pulse SSP mode, regardless of the SSP mode’s repetition rate.

Discussion
The goal of endodontic treatment is to obtain effective cleaning and decontamination of the smear layer, bacteria and their by-products within the root canal system.
Clinically, traditional endodontic techniques use mechanical instruments, as well as ultrasonic and chemical irrigation in an attempt to shape, clean and completely decontaminate the endodontic system, but still fall short of successfully removing all of the infective microorganisms and debris. The latest SSP/SWEEPS® technology greatly simplifies root canal therapy while successfully addressing all of the ultimate goals of endodontic irrigation: 3D streaming of the irrigant throughout the complex root canal system, increased penetration of the irrigant deeper into the dentinal tubules, removal of debris and smear layer from the root canal system, more effective chemical activation of NaOCl, direct (non-chemical) removal of biofilm, and direct (non-chemical) disinfection.

3D irrigant streaming
The high absorption of temporally super-short Er:YAG laser light leads to explosive boiling of the irrigant that generates oscillating vapor bubbles causing the mixing of liquid also at distant regions of the complex root canal anatomy. Observations of debris particles show that liquid vorticity effects continue long after the bubble oscillation has ended, significantly contributing to the SSP/SWEEPS® irrigation efficacy (Fig. 6). Using the SSP/SWEEPS® technique, it is now possible to effectively debride and disinfect isthmic, cul-de-sacs, lateral canals, and apical ramifications. SSP irrigation efficacy has been previously studied using a root canal model with a lateral canal (Fig. 7). The fluid motion achieved within the lateral canal during SSP activation was at a speed of 1.5 mm/s, which is sufficient for the irrigation of any lateral canal.

Penetration of irrigants into dentinal tubules
Traditional irrigation during root canal treatment with a syringe and needle is associated with only limited penetration beyond the main canal into dentinal tubules. The limitation is particularly pronounced in the apical area. The SSP/SWEEPS® activation considerably increases the efficacy of the irrigants in the apical area, as demonstrated also by the pressure measurements in this study. The pressure measurements during SSP activation show the pressures in the apical region to be significant, by a factor of only 1.6-times smaller than the pressure in the coronal region (Fig. 4). This is in agreement with a study, which compared different methods of activation of endodontic irrigants including ultrasonic, sonic and SSP, and determined that SSP activation achieved the greatest penetration depths in the middle and apical sections.

Cleaning—removal of debris and smear layer
The present study shows that the latest SWEEPS® modality significantly enhances the debris removal efficacy even in comparison to the SSP irrigation (Fig. 5). As an example, Figure 8 shows the observed difference in the efficacy of debris removal of the SSP and SWEEPS® irrigation.

Activation, disinfection and biofilm removal
A major mechanism of action of the SSP laser-activated root canal irrigation techniques is believed to be the rapid fluid motion in the canal as a result of expansion and implosion of vapor bubbles, resulting in a more effective delivery of the irrigants throughout the complex root canal system. An additional mechanism which contributes to the efficacy of SSP is the improved removal of the smear layer, microorganisms, and biofilm as a result of the physical action of the turbulent irrigant. In addition, chemical action seems to play a role as well. For example, an increased reaction rate of NaOCl was found to occur upon activation by the pulsed erbium laser. By
being able to generate shock waves within narrow root canals, both the physical and chemical actions of SSP can be potentially further enhanced by using the SWEEPS® technique.

**Minimal risk of extrusion**

It is important to note that the SSP/SWEEPS® irrigation does not result in any increase of apical irrigant extrusion. Recently, a study of the apical irrigant extrusion during SSP and SWEEPS® laser irrigation was carried out, during which irrigation using two standard endodontic irrigation needles (notched open-end and side-vented) was compared with the PIPS and SWEEPS® laser irrigation procedures. In the standard irrigation experiment, the irrigation device was a syringe coupled to either a 30G open-ended or side-vented needle, with flow rates of 1, 2, 5 and 15 mL/min. Both the PIPS and SWEEPS® irrigation procedures resulted in a significantly lower apical extrusion compared to the conventional irrigation with endodontic irrigation needles, in agreement with previous reports.

**Optimal fibre tip for SSP/SWEEPS® endodontics**

Pressure measurement results (Fig. 3) show that in general the pressure generation efficacy is higher for smaller fibre tip diameters. The highest efficacy was observed for the following cylindrical tips: Radial Sweeps400 and Flat Sweeps400 tips, with no significant difference between the two fibre tip types. For the larger fibre tip diameter of 600 mm, the radially-ended fibre tip was slightly more effective than the flat-ended tip. This is because radially-ended tips generate spherically shaped bubbles where optodynamic energy conversion efficiency is optimal, while flat-ended tips tend to generate more spheroid-shaped bubbles. This difference becomes less pronounced for smaller fibre tip diameters where bubbles become approximately spherical regardless of the fibre tip ending.

The SSP irrigation has been typically performed using the PIPS 600 mm fibre tip, geometrically equivalent to the Radial Sweeps600 tip. However, based on the results of the present study, the narrower Radial Sweeps400 fibre tip is even more effective and therefore appears to be a preferred choice. On the other hand, when fibre tip longevity is of concern, the appropriate choice is the Flat Sweeps400 tip. This tip was found to exhibit the same pressure efficacy as the radially-ended tip (Fig. 3), however, it is more durable, especially when performing SWEEPS® activation where the radial fibre tip’s cone can get more readily damaged by the generated shock waves.

**Conclusion**

Our study indicates that the combined SSP/SWEEPS® technology of the SkyPulse Er:YAG laser system has the potential to greatly simplify root canal therapy while successfully addressing the major goals of endodontic irrigation. The ability of SSP/SWEEPS® to three-dimensionally debride and decontaminate dentinal tubules thus allows the clinician to effectively deliver treatments in less time and with less need to enlarge the canal system, allowing for a more minimally invasive preparation.

* Previous manufacturer’s codes for cylindrical 400, 500 and 600 µm fibre tips were Varian400, Varian500 and Varian600, correspondingly.

** Previous manufacturer’s codes for tapered cylindrical 400 and 600 µm fibre tips were XPulse400 and XPulse600, correspondingly.

**about**

Dr Tomaž Ivanušič graduated from the University of Ljubljana’s Faculty of Medicine in 2017. Thereafter, he served a one-year internship, where he gained experience in different dental specialities. Primarily focussing on Endodontics, Restorative Dentistry and Laser Dentistry, Dr Ivanušič currently works as a dentist in a private clinic in Slovenia.

In addition, he works as researcher, lecturer and trainer, and has been involved in the development of laser systems including the Fotona SkyPulse.

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Managing refractory endodontic disease with radial apical cleansing

Dr Justin Kolnick, USA

Introduction

One of the defining attributes of an astute endodontist is the ability to successfully treat refractory endodontic disease. Refractory disease is defined as disease that is recalcitrant, unresponsive, stubborn, unmanageable or resistant to treatment or cure. While the pathogenesis of refractory endodontic disease is not clearly comprehended, it is highly likely that microbiological and host immune influences play an important role. Unsuccessful endodontic outcomes are often attributed to persistent infection perpetuated by entombed bacteria or by reinfection of a previously disinfected root canal system, commonly via coronal leakage or tooth fracture. Extra-radicular causes are less common and include periapical actinomycosis, cholesterol crystals, foreign body reactions, unresolved cystic lesions and extra-radicular biofilm, and usually require surgical intervention or extraction of the tooth.

Refractory endodontic disease

Figures 1a–d show an example of such a clinical case. It was posted online by an endodontist and is presented with his permission. It involved retreatment of a mandibular right first molar with a diagnosis of symptomatic periapical periodontitis. Periodontal probing measurements were normal and there was no evidence of a tooth fracture. A CBCT scan was taken, but it was not posted. The treatment followed a standard endodontic protocol with long-term application of calcium hydroxide that was reapplied twice over a period of seven months. As the patient’s symptoms improved somewhat, the canals were obturated and the tooth restored. A week later, the tooth was extracted owing to persistence of symptoms.

Although the aetiology of the failed treatment and inability to resolve symptoms was never ascertained, a strong possibility is that the protocol used was ineffective in reducing the bioburden within the tooth sufficiently. Mandibular molars are known to have a complicated root canal system, especially in the mesial root (Figs. 2a & b), and current instrumentation and irrigation techniques fall short of adequately addressing this anatomy.

Case 1

The patient was a 58-year-old male dentist with a history of thyroid cancer. He had been diagnosed with recurrent endodontic disease in his mandibular right second molar. Retreatment was initiated by his endodontist. He presented in my office complaining of pain on percussion to the tooth. He had seen his endodontist multiple times over a period of several months, but there had been no improvement in his symptoms. Occlusion was light on the tooth. Periodontal probing depths were normal, and transillumination showed no signs of a tooth fracture. A diagnosis of symptomatic periapical periodontitis was made. The CBCT scan showed no evidence of untreated root canal anatomy or of a root fracture (Fig. 3).

Under local anaesthesia, the tooth was treated with the radial apical cleansing (RAC) protocol and re-medicated.
with calcium hydroxide paste (Figs. 4a–c). A prescription for amoxicillin (500mg, three times a day for seven days) was given. At the second visit, three weeks later, the tooth was asymptomatic and was obturated with a bioceramic sealer and single-cone gutta-percha technique (EndoSequence BC Sealer and Points, Brasseler). At the patient’s 1.5-year follow-up, the tooth was functional and asymptomatic, showing normal probing and radiographic evidence of complete healing. The tooth had not yet been permanently restored.

Case 2

A 77-year-old female patient presented with pain and swelling associated with her mandibular left first molar. She had previously been treated by two endodontists who were unable to relieve her symptoms (Figs. 5a & b). Examination revealed swelling in the adjacent mucobuccal fold, and the tooth was sensitive to percussion. Periodontal probing was normal except for a narrow 7 mm pocket on the buccal aspect of the mesial root. Transillumination showed no signs of a cracked tooth. Radiographic examination showed a J-shaped radiolucency on the mesial root and a smaller apical radiolucency on the distal root. The CBCT scan confirmed the extent of the findings, as well as evidence of loss of the buccal plate on the distal root (Fig. 6). A diagnosis was made of symptomatic periapical periodontitis with a buccal draining sinus along the periodontal ligament space.

Under local anaesthesia, the tooth was treated with the RAC protocol and re-medicated with calcium hydroxide paste (Figs. 7a–d). The patient was prescribed amoxicillin (500mg, three times a day for seven days). At the second visit, three weeks later, the tooth was asymptomatic and was obturated with a bioceramic sealer and single-cone gutta-percha technique (EndoSequence BC Sealer and Points). At recall, nine months later, probing depths were normal, and the tooth was functional and asymptomatic and showed evidence of osseous healing.

Radial apical cleansing

RAC is a treatment protocol that consistently achieves superior cleaning and disinfection of complicated root canal.
systems, utilising a chemomechanical protocol assisted by the application of radially firing laser energy. It entails instrumentation, irrigation, cleansing and disinfection.

**Instrumentation:**
1. A glide path is established with 0.06 and 0.08 hand files and rotary nickel-titanium (NiTi) path files.
2. Deep apical shaping is performed with heat-treated NiTi files, always preserving root structure, especially in the coronal third and peri-cervical zone.

**Irrigation:**
1. Effective apical negative pressure irrigation is performed with the EndoVac system (KaVo Kerr) using a 6% sodium hypochlorite (NaOCl) solution.
2. Sonic activation of the irrigant is performed.

**Cleansing:**
Laser-activated irrigation is performed with an Er,Cr:YSGG laser (Waterlase iPlus, BIOLASE) using the RFT2 and RFT3 laser tips with the following settings: 1.25 W, H mode, 20 Hz (pulses per second), 30% air, 10% water and 62.5 mJ/pulse.

**Disinfection:**
1. Laser disinfection is performed with an Er,Cr:YSGG laser (Waterlase iPlus) using the RFT2 and RFT3 laser tips with the following settings: 1 W, H mode, 20 Hz (pulses per second), 10% air, 0% water and 50 mJ/pulse.
2. Deep dentinal disinfection is performed with a 940 nm diode laser (Epic X, BIOLASE) using an uninitiated laser tip at 1 W and in continuous wave in a wet canal. This is an off-label use of the diode laser in the US, as no clearance has been issued for this application by the U.S. Food and Drug Administration (FDA).

Ideally, for both cleansing and disinfection, the laser tip is placed 1 mm short of working length and activated on withdrawal of the tip, in a circular motion, at a rate of

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**Figs. 4a–c:** Pre-op (a). Post-op (b). Recall at 1.5 years (c).

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**Figs. 5a & b:** Images from previous endodontist. **Fig. 6:** CBCT slices showing a J-shaped finding on the mesial root and a smaller apical finding on the distal root.
1–2 mm per second. This process is repeated four times in each canal. Placement of the laser tip is influenced by the root canal anatomy, diameter and flare of the prepared canal, and the presence or absence of canal patency. The tip will remain effective even at distances of 5 mm or more from the apical foramen.

Erbium lasers in endodontics

Erbium lasers have emerged as the most promising laser wavelength in endodontics. They can be used on both hard and soft tissue and have the most FDA clearances for a multitude of dental procedures. Their primary chromophores are water and, to a lesser degree, hydroxyapatite. Photothermal interactions prevail in soft-tissue procedures and photo-disruptive interactions in hard-tissue procedures. When proper parameters are followed, thermal relaxation is excellent and there is minimal collateral thermal damage to surrounding tissue.

Action in root canal systems

When laser is activated in the presence of water, instantaneous vaporisation occurs, creating a vapor bubble at the end of the radially firing laser tip (Fig. 8). The rapidly expanding and implooding bubbles create a cavitation effect with high-velocity water jets forming shear stress along the canal wall. Secondary cavitation effects from canal irregularities also contribute to the cleaning and sterilisation potential of the treatment.

At liquid–solid boundaries (canal walls), microscopic bubbles are generated by the shear forces from the passing acoustic wave, resulting in a micro-streaming and micro-cavitation effect that can permeate canal ramifications and dentinal tubules (Fig. 9). Expansion and collapse of intratubular water are possible at a depth of 1,000 µ or more, and are capable of producing acoustic effects strong enough to disrupt biofilm and kill bacteria.16

Discussion

Endodontic disease is essentially a biofilm-mediated disease and the success of endodontic therapy depends to a large extent on the ability to remove biofilm and to kill biofilm bacteria. To achieve this end, endodontic therapy has relied on chemomechanical debridement of the root canal system. Owing to the complexity of root canal anatomy, about 30–45% of the root canal system remains untouched by mechanical instrumentation,1 and over-instrumentation will further weaken the tooth and may influence apical crack initiation.2 As a result, more reliance has been placed on the efficacy of disinfecting agents for the killing of biofilm bacteria as opposed to planktonic bacteria. Biofilm bacteria can be up to 1,000 times more resistant to antibacterial agents than their planktonic counterparts are.3

Previous studies have shown that instrumentation and antibacterial irrigation with NaOCl eliminated bacteria in 50–75% of the infected root canals at the end of the first treatment session, whereas the remaining root canals contained recoverable bacteria.4,5 In their study, Nair et al. showed that 88% of endodontically treated mandibular molars showed residual infection of mesial roots after instrumentation, irrigation with NaOCl and obturation in a one-visit treatment.6 For antimicrobial agents to be effective, they need to reach the canal terminus, carry undissolved particles away, create a current and be continuously replenished. Chow illustrated that there is little flushing effect beyond the tip of a side-vented needle.7 In addition, the dissolving action of NaOCl on intra-canal
tissue releases bubbles that can coalesce to form apical vapor lock that promotes poor apical cleaning by pre-venting irrigants from reaching the canal terminus. Apical negative pressure irrigation has been shown to be ex- tremely effective in overcoming these obstacles, but is becoming increasingly difficult to use with the smaller ca-nal shapes being advocated with minimally invasive end-odontic principles.

Laser-activated irrigation (LAI) generates stress waves strong enough to disrupt biofilm, thereby releasing bac-teria into their planktonic state. This may occur owing to either cohesive failure, disrupting superficial lay-ers, or adhesive failure, completely removing the biofilm. This makes the bacteria more susceptible to the biocides (intra-canal irrigants and medicaments) used for canal disinfection. There is also a reported direct effect on the bacteria themselves, increasing bacterial permeability by creating temporary pores in their membranes and dam-maging cell surfaces. If the shear forces generated are insufficient to break down the cohesive bonds of the vis- coelastic biofilm matrix, the biofilm will simply deform and return to its original state. Insufficient forces may be gen-erated with the use of sonic or ultrasonic agitation or if the laser tip placement is too distant from the biofilm. LAI has also been shown to effectively remove the smear layer and dentinal plugs, thereby playing an important role in maintaining and re-establishing canal patency. Removal of apical vapor lock is another advantage of LAI and occurs by disruption of the surface tension at the solu-tion–air interface.

Laser disinfection is an important element of RAC and occurs with the application of the Er,Cr:YSGG laser in the dry mode. The laser energy seeks out the water in infected tissue, the highly hydrated biofilm matrix, as well as the bacteria themselves, resulting in ablation of the targeted tissue and microorganisms. The end result is effective disinfection to a depth of 200µ into dentine. Deeper dentinal disinfection has been reported with the diode laser, and the dual laser approach has been showing promise in vitro. The primary chromophores for the diode laser wavelength are pigment (melanin and haemoglobin) and, to a lesser degree, water. This results in greater light penetration through dentine with little in- teraction with it, making it possible to reach and destroy microorganisms deeper in the dentinal tubules.

Conclusion

The challenge presented by refractory endodontic dis-ease can be summed up by Ricucci et al.: “[We need] to develop strategies, instruments or substances that can reach those areas distant from the main root canal to achieve sufficient reduction in the infectious bioburden to permit predictable periradicular healing.” A treatment protocol, RAC, has been presented for non-surgical management of refractory endodontic dis-ease. The protocol relies primarily on a synergistic effect between Er,Cr:YSGG laser irradiation and subsequent apical negative pressure irrigation with 6% NaOCl, which promotes disruption and destruction of biofilm bacteria within complex root canal systems and dentinal tubules. While several studies have focused on identifying root canal microflora in recalcitrant cases in an attempt to explain the pathogenesis of refractory disease, it is the contention of this author that RAC is a valuable tool capable of successfully treating the infectious bioburden, irrespective of the make-up of the biofilm itself. In the two case reports presented, the only significant deviation from standard endodontic protocols was the introduction of laser-assisted endodontic cleaning and disinfection.

Editorial note: A list of references is available from the publisher. This article originally appeared in Oral Health Magazine and an edited version is provided here with permission from Newcom Media.

For the past 36 years, Dr Justin Kolnick has been in a private practice, limited to endodontics, in Westchester County in New York in the USA. He received his dental training in South Africa and specialised in endodontics at Columbia University in the City of New York. He lectures extensively on endodontics on a local, national and international level. Dr Kolnick is a clinical mentor for BIOLASE.
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Part IX: Boosting a new employee’s performance

Dr Anna Maria Yiannikos, Germany & Cyprus

This series covers the most common and challenging scenarios that might arise in your dental practice and presents successful ways to deal with them in order for you to gain peace of mind. Each article of this series teaches you a new, easy-to-use specialised protocol that can be adapted to your own dental clinic’s requirements and needs right from the start. Today’s challenging topic is how to address deterioration of a new employee’s performance and, instead, find ways to boost it.

Imagine this scenario: You have chosen an excellent employee. You’ve tested him or her and he or she performed exceptionally well. However, what if after a month or so you notice that his or her performance is not as promising as it was when he or she started? You might start to wonder: Have I made the wrong choice? Where did his or her motivation go? Does he or she feel bored all of a sudden? Is something wrong in general?

5 revolutionary steps

A sudden decline in the performance of a new employee is quite unusual. Naturally, you still have faith in his or her capabilities and all you want is to get to the bottom of this unexpected, and thus scary, situation and solve it. Follow the five steps given here and you will be able to deal with this situation easily, effortlessly and effectively.
1. Always check yourself first before you even think about confronting him or her; reflect on your own behaviour first. Challenging your attitude and calling it into question is a difficult, but necessary thing to do. Try to find out whether your employee’s performance is likely to continue to decline or if it was just a one-time thing. After all, every human being makes mistakes. Hence, stop making assumptions and save yourself a great deal of stress. After you have reflected thoroughly on your own behaviour, block off 45 minutes in your schedule and call him or her in for a meeting in order to address the problem. By the way, do not allow yourself to be disturbed during this meeting.

2. Keep the tone of the conversation natural and casual. It is very important to create an environment in which the employee feels comfortable enough to express himself or herself and share the true reasons for his or her reduced performance. Always remember: do not pressure your employee. Knowing the reasons for his or her poor performance will, of course, benefit you, as you will be more aware from that point on, and, thus, you will be able to anticipate similar future situations and solve them faster.

3. The sandwich technique can prove a very useful tool for solving those kinds of situations. You begin by saying: “Mary, I am so happy that you are part of our team”. You continue by stating a fact: “You showed us right from the start how keen you are to be working in the company. However, over the course of the last week, I’ve noticed a deterioration in your performance, and ever since, I have been wondering what the reason might be for that.” You can then conclude by saying: “I am confident that we can deal with this situation effectively and I am here to assist you. What do you need from us?”

4. Give the employee space to express himself or herself and do not interrupt him or her. Try to show empathy and put yourself in his or her shoes. Consider: What is the actual problem? Is he or she just anxious about failing in his or her new position, because of too much pressure? Does he or she only need some time to adjust to the new professional situation? Whatever the reason is, you should acknowledge and respect it. And make sure you have a mutually developed plan or protocol by the end of your conversation and act accordingly.

5. Set a date for a future meeting in order to re-evaluate the situation and the development after the initial conversation and see whether things have changed for the better by then. You can ask the employee to set a date for this next meeting himself or herself. This will help him or her to feel responsible, in charge of the whole situation and in control of his or her own behaviour.

Isn’t that easy?

As you can see, applying the 5 steps is not so difficult, is it? Use these steps as a protocol and you will feel prepared and in control the next time such an undesirable situation occurs. You now know the exact steps to resolve situations like these quickly and efficiently. By applying this protocol, I believe that you will achieve greater peace of mind in the long run. In addition, you will have a great deal more time and energy on your hands. Just try it and let me know what you think!

I am certain that you are already looking forward to the next issue of roots magazine, in which I will present the tenth part of this unique series of communication concepts and touch on further useful and interesting topics. Are you curious about what’s next? We will take an honest look at how to deal with your own procrastination, as well as how to transform someone who is constantly complaining into a loyal patient. This is a common and challenging situation that we as dentists face in our clinics. In this regard, I will provide five essential tips that will help you to cope with these situations more effectively.

Until then, remember that you are not only the dentist at your clinic, but also its manager and leader. For questions and further information and guidance, keep in touch by sending me an e-mail at dba@yiannikosdental.com or via our website, www.dbamastership.com. I am looking forward to our next step towards business growth and educational development!

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Munich has been home to the endodontic manufacturer VDW for 150 years. After having developed over several decades at various locations scattered throughout Munich, the team, led by General Manager Sonja Corinna Ludwig, moved into the present headquarters in the south of the Bavarian state capital in 1995.

Modern technology meets traditional handiwork: The production facilities

A glimpse behind the scenes of the 3,000 m$^2$ of the production halls reveals that, alongside state-of-the-art, highly automated manufacturing technology and high-performance robots, traditional handiwork plays a role that is more significant than ever. That is because it is only by working by hand that the most minuscule manufacturing errors can be detected and the highest possible standards of quality can be assured. In total, there are more than 110 machines in use, of which as many as 80% are custom-made. Other interesting facts are that an average of ten production steps are required to create the finished product and that 12 types of steel are used to manufacture over 800 different VDW instruments. The results speak for themselves: each year, over 60 million endodontic products are manufactured and distributed all over the world. There are 100 employees working on this every day.
Training is top priority: VDW’s own training centre at its headquarters

A total of almost 800 courses offered and 15,000 dentists qualified per year—those are the impressive figures for the VDW training programme. VDW’s own training centre at its Munich headquarters is also quite remarkable. It has been growing since 2004 and comprises 22 workstations equipped with microscopes and the latest VDW equipment. This includes professional presentation technology with a microscope for the lecturers, which enables video transmission via the projector. There is also a digital radiographic device in the next room, which allows participants to directly control their training results and transmit the image into the training room. Courses presented by renowned lecturers and endodontic specialists take place almost weekly at the training centre in Munich, for trainers, dentists, students and even VDW’s own employees. In addition, industry associations such as the German society of endodontics and traumatology (Deutsche Gesellschaft für Endodontologie und zahnärztliche Traumatologie e.V. [DGET]), APW and eazf (European academy of dental education and training of the Bavarian state dental association) are welcome to host their own events.

Welcoming atmosphere: Modern new building in south Munich

At VDW’s present headquarters on the southern outskirts of Munich, staff offices and production facilities are spread over the three floors of a modern building. The atmosphere is friendly and open—and a passion for endodontics evident. Everything is geared towards growth—VDW has expanded by 40% in the last five years alone. This year, there are now about 200 employees from 17 nations working in endodontics at VDW, and more than a third of them have been employed by the company
for over ten years. The highlight of the building, as everyone agrees, is the spacious roof terrace with breathtaking views of the mountains—in good weather, you can actually see 150 peaks from various angles. This space is used for lunch-breaks, as well as for creative meetings or discussions between colleagues.

Where innovations arise: Research and development department

VDW is a pioneer in root canal therapy, and with Dr Sarah Poschenrieder at the helm, the research and development department brings together 150 years of knowledge with a constant spirit of innovation. The recently redesigned research and development colosseum serves both as a technical office and a development and testing centre. “We are the nerve centre for new ideas and innovations. We don’t do standing still here,” says Poschenrieder. Many groundbreaking innovations have already been born here: from the worldwide ISO standard colour coding to a revolutionary reciprocating system. An absolute development record for VDW took place here too: for the RECIPROC blue file system, it took less than a year from the initial idea to the prototype. The innovativeness of VDW products has been recognised with innumerable awards, including the renowned iF DESIGN AWARD for the product design of the VDW.CONNECT Drive.

The spirit of VDW: Down to earth and focused on the future

Since 2018, Sonja Corinna Ludwig, Director of Global Sales and General Manager, has been managing VDW in Munich together with her five-strong leadership team.
Recently, the plant was one of two in Europe to be awarded the FM Global Award for its outstanding work on processes and measures for safety and risk minimisation. “We set the highest standards in all areas—from production to marketing. And above all, we at VDW work as a true team. Every employee is appreciated and welcome to contribute his or her ideas and ultimately to push endodontics forward,” says Ludwig. There is a special reason to celebrate in 2019, as the brand marks its 150th birthday! Under the slogan “Join our ride”, VDW is bringing together its partners, customers and employees to celebrate and look forward to its bright future.

Committed to sustainability

Contributing to the sustainable development of society, in terms of environmental, economic and social responsibility, has always been high on VDW’s list of priorities. Through its latest initiative, the company is making an active commitment to achieving greater biodiversity and taking on more ethical responsibility. Since spring, 12 bee colonies, comprising around 30,000 bees, have been housed on the roof of the Munich headquarters, where they are looked after by a professional beekeeper. Customers, employees and trainees are already looking forward to VDW’s very own rooftop honey. We are sure that there will be plenty of people willing to sample it—purely for quality assurance purposes, of course!
ROOTS SUMMIT 2020: Registration is now open

By Dental Tribune International

Online registration for the next ROOTS SUMMIT, the premier global discussion forum dedicated to endodontics, is now open. The event, featuring lectures and workshops, will be held at the Cubex Centre Prague from 21 to 24 May 2020. Approximately 500 visitors are expected at next year’s ROOTS SUMMIT, which is again being organised in collaboration with Dental Tribune International.

Although ROOTS SUMMIT 2020 will mainly feature presentations on the latest techniques and technologies in endodontics, the organisers are inviting dental professionals in all fields, as well as manufacturers in the industry, suppliers of endodontic products and anyone involved in the practice of endodontic treatment, to attend.

It has been announced that foremost opinion leaders, including Drs Daniel Černý, Gianluca Plotino and Maxim Belograd, and Profs Gianluca Gambarini and Matthias Zehnder, will be speaking at the conference next year. In addition to the lecture programme, attendees will have the opportunity to participate in hands-on workshops, speak to industry professionals and engage with new equipment, procedures and protocols in endodontics. A number of dental companies specialising in endodontics, including Henry Schein, Laschal Surgical, CJ-Optik, Seiler Instrument and Global Surgical, have already confirmed their participation.

ROOTS SUMMIT, which started as a mailing list of a large group of endodontic enthusiasts in the 1990s, has grown significantly over the last few years. With currently more than 24,000 members from over 100 countries, ROOTS SUMMIT has evolved into one of the most prominent global learning forums in the dental industry. Previous conferences have been held in Canada, the USA, Mexico, the Netherlands, Spain, Brazil, India and the UAE. The 2018 ROOTS SUMMIT took place in the German capital of Berlin.

An early bird discount of 20% is being offered and also a 30% academic discount will be granted. Additional information and online registration can be found at www.roots-summit.com. Dental professionals are invited to like the ROOTS SUMMIT Facebook page to receive the latest updates.
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<th>Dates</th>
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<tr>
<td>GNYDM</td>
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<td>São Paulo, Brazil</td>
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<td>24–26 April 2020</td>
<td>Singapore</td>
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Questions?

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