clinical review
Use of 3D technology in the diagnosis and treatment of endodontic disease

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Better technology and referral relationships—Are they related?

Advancements in technology have made it easier for dental professionals to deliver successful endodontic treatment. Nevertheless, endodontics continues to be a specialty that is best handled by trained experts.

It is appropriate for a general dentist to perform endodontic treatment on a patient when he or she is properly trained to perform the said procedure, has the appropriate equipment and possesses the requisite skill set for the treatment. However, if there is any doubt that the clinician can perform the procedure to the same standard of practice as an endodontic specialist, the case should be referred out. The American Association of Endodontists offers its case difficulty assessment form and guidelines to help general practitioners with case selection.

Rapid advancements in endodontic technology have permitted dental professionals to enjoy higher success rates. Patients can retain their teeth for as long as possible, reducing the need for retreatment and/or extraction, and thereby limiting the high costs they once faced.

The dental operating microscope is a prime example. As it enables clinicians to visualise the anatomy of the pulp chamber, they can locate the canal anatomy more proficiently and offer minimally invasive treatment by keeping access openings as small as practical while maintaining the structural integrity of the tooth. In addition, practitioners are able to maintain a more ergonomically favourable position, thereby reducing stress on their back and neck.

Ultrasonic instruments with specially designed endodontic tips allow clinicians to uncover calcified canals, remove pulp stones, refine access preparations, and remove posts and cores. They aid in the debridement of the root canal system during irrigation protocols in a controlled and predictably safe manner.

Cone beam computed tomography (CBCT) offers unprecedented accuracy and acuity. We can visualise the tooth in 3D; it is like a road map to the anatomy of the root canal system. In addition, the resolution of the CBCT is higher than that of traditional radiography, allowing the detection of periradicular pathology, which may have otherwise gone undetected. The type, location and extent of internal/external resorption can now be definitively diagnosed and the relationship of normal anatomical structures can be assessed with ease.

Dental service organisations offer specialists like endodontists an opportunity to connect with general dentists and their patients, who may require advanced care. An open dialogue between endodontists and their general dentist colleagues will help ensure that patients receive the best possible treatment. Plus, the accessibility of the patients through their general dentist’s office is often more practical and convenient, both for the patients and the practitioners.

Communication and continuing education are key components of the relationship between endodontists and general dentists, noting that a true partnership between practitioners ultimately leads to better patient care.

Dr Gary Glassman
Guest Editor
editorial
Better technology and referral relationships—Are they related? 03
Dr Gary Glassman (Guest Editor)

clinical review
Use of 3D technology in the diagnosis and treatment of endodontic disease 06
Dr Fabio Gorni

case report
Apicectomy of an endodontically compromised central incisor 12
Drs Georgi T. Tomov & Mutlu S. Turkkan

industry report
Laser enucleation of a radicular cyst with the PIPS protocol 16
Dr Betül Göfteci

materials
Obturation materials in a state of flux—fluid boundaries between biocompatibility and bioactivity 20
Dr Barbara Müller

trends & applications
Irrigation in curved canals 24
Drs Francesca Cerutti & Riccardo Tonini

The use of pre-mixed bioceramic materials in endodontics 28
Drs Gilberto Debelian & Martin Trope

opinion
Next-level endodontic restorative continuum—a new perspective Root to restoration 36
Dr Kenneth S. Serota

practice management
Successful communication in your daily practice Part VII: Special services for VIP patients 44
Dr Anna Maria Yiannikos

manufacturer news
46

interview
“Join our ride!”—VDW celebrates its 150th anniversary 48
Interview with Sonja Corinna Ludwig

meetings
IDS 2019: Leading global trade fair of the dental industry reaffirms its position 50
International Events 54

about the publisher
submission guidelines 56
international imprint 58
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3D mapping of bone density for improved success rate

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In recent years, the technology associated with endodontic therapy has undergone a veritable revolution. For years, intraoral radiographs were used as the basis for diagnosis and for planning root canal therapy, despite the fact that these images did not provide a faithful reproduction of the endodontic anatomy. This created a series of technical problems, which, although they could be partly overcome by the operator’s personal experience, to some extent remained unresolved, especially in the field of diagnosis.

I personally started using cone beam computed tomography (CBCT) for endodontic purposes more than ten years ago. Although the machines that I used then were far from ideal for this specific purpose, the possibilities offered today by increasingly sophisticated technologies have greatly improved my diagnostic and interventional capabilities. In order to make an accurate diagnosis, an endodontist needs to perform a highly detailed assessment of the canal and pulpal anatomy, which requires high-definition examination techniques and software that enables the endodontist to rotate the tooth accurately and easily. This may seem obvious and trivial, but is not. Indeed, over the past ten years, I have had the opportunity to work with a large number of devices and dozens of software programmes, but only very few have proven to be suitable for endodontic purposes. For a few years now, I have been using ACTEON’s trium technology, with extremely satisfactory results. The imaging is very accurate and highly detailed, and above all, the user friendliness of the ACTEON Imaging Suite makes it possible to identify even slight differences between the different radiographic slices, differences that are of paramount importance for making a correct endodontic diagnosis and for the therapeutic decision-making process itself. Clinician experi-
ence alone is not sufficient for establishing the correct approach to be adopted in the case of endodontic disease, and very often clinical cases that were initially scheduled for orthograde treatment, after CBCT assessment, turn into cases for endodontic surgery or vice versa. We can therefore state that the capability we have now of performing these studies in a quick and easy manner has drastically reduced the number of incorrect diagnoses and, consequently, the number of clinical errors.

The case with which I would like to start my clinical review is a perfect example of how difficult it is to establish the origin of the patient’s symptoms on the basis of an intraoral radiograph alone. Not only does the 2D study fail to establish with certainty the presence of a lesion, but more importantly, it is impossible to establish the size, morphology and type of the lesion. An analysis of the 3D imaging, however, provides a clear picture of the clinical situation: the coronal and sagittal slices revealed the presence of a large lesion extending from the apex of the mesial root of this molar to the furcation, while the axial slices allow us to conduct a precise analysis of the endodontic anatomy and, in particular, the shape of the mesial root, which in this case was fused with the palatine

---

**Fig. 7**

**Fig. 8**

**Fig. 9**

**Fig. 10**

**Fig. 11**

**Fig. 12**

**Fig. 13**

**Fig. 14**

**Fig. 15**

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**roots**

2 2019 107
A full overview of the case can, therefore, guide the decision-making process and direct the treatment plan towards a specific type of treatment (Figs. 1–4).

In the maxillary premolar shown in Figures 5 and 6, the fistulogram revealed the presence of an apical lesion that extended coronally to approximately the middle third of the root. The clinical decision could, therefore, propend towards orthograde retreatment; however, CBCT gave us a very different view of the situation compared with the radiograph, as it indicated that a prior treatment had irreversibly damaged the tooth, which would therefore have to be extracted.

The situation was entirely different for the mandibular premolar shown in Figures 7 to 9, where, in the absence of any radiological signs of a lesion and despite the apparently correct endodontic approach adopted by another colleague, the patient complained of persistent pain which was both spontaneous and triggered by percussion of the tooth. In this case, the previous excellent root canal therapy would suggest an endodontic surgery approach, which could guarantee a higher success rate than retreatment. Given this diagnostic doubt, it was decided to perform a 3D study, which revealed an endodontic lesion caused by an untreated lingual canal. This correct diagnosis, thus, made it possible to perform selective intervention on the remaining pulp, leading to successful treatment of the untreated canal.

Undeniably, one of the most complex conditions to treat is external invasive root resorption, where the extent of the defect affects the treatment options. It therefore becomes sensible to perform a preoperative evaluation of the location and extent of the resorption, and the potential for recovery, thus, depends on correct 3D planning of the procedure, which can only be achieved after examination of the CBCT images. It is very important to be able to view the slices of the tooth correctly in all three planes, focusing in particular on the axial slices, which will prove to be strategic from an endodontic diagnosis point of view.

Comparing the two teeth shown in Figures 10 to 22 demonstrates just how important it is to analyse all the slices of the CBCT study correctly. We can see that, in the maxillary molar, the lesion penetrates into the pulp chamber, starting from the root’s distal surface, but remains within the coronal third of the tooth, without sig-
nificantly affecting the integrity of the pulp chamber floor (Figs. 10–15). The clinical images illustrate the operative treatment phases, from resorption debridement through to repair using bioceramic cement (Figs. 16–19). The final radiographic images confirm the validity of the conservative and endodontic treatment of the tooth. The situation is completely different for the mandibular molar, where the evaluation of the CBCT scan clearly reveals the extent of the resorption, which invades the pulp chamber floor until the furcation, a situation that cannot be determined from observing the preoperative radiograph alone (Figs. 20–22).

Preoperative CBCT evaluation is useful in cases requiring a surgical approach, not only in order to confirm the presence of a lesion but also to plan the procedure and, in particular, identify the type of surgical incision to be used, based on its size and location (Figs. 23–25). This specific case is characteristic of this situation. The intraoral radiograph did not make it possible to ascertain
the extent of the lesion, which involved not only the apical region of the premolar but also a distal edentulous segment. This region would need to be treated with regenerative therapy in order to guarantee correct healing of the area, with subsequent insertion of a membrane, the flap must be protected using a totally different approach to that required for endodontic surgery. The intraoperative images illustrate the various stages of the procedure (Figs. 26–28). The CBCT scan performed 12 months later confirmed complete healing of the apical lesion and perfect graft integration (Figs. 29–31).

Another compelling advantage of this 3D technology is the possibility of using a minimally invasive approach for performing cavity access. For demonstration, the next case involves a dens in dente. The CBCT scan shows a separation between the two canal systems of the canine and the decay involves the portion of tooth where the dens in dente is present. The treatment plan therefore involved root canal therapy for just one portion of the pulp, while the other was to be kept vital. The image sequence of the treatment shows how it was possible, using CBCT and a surgical microscope, to perform a minimally invasive access, which spared much of the canine’s clinical crown and kept the disease-free portion of the tooth vital. The radiographic follow-up confirmed complete healing of the lesion and the vital part of the canine did not present any signs of disease six years later (Figs. 32–37).

about

Dr Fabio Gorni was a consulting professor in endodontics at the San Paolo hospital associated with the University of Milan in Italy. He is an active member of the Italian Society of Endodontics and of the Italian Academy of Microdentistry, a specialist member of the European Society of Endodontology and a member of the American Association of Endodontists. From 1994 to 1998, he served on the member acceptance committee of the Italian Society of Endodontics, and from 1998 to 2001, he was the society’s cultural secretary. He was president from 2003 to 2005. He has lectured at several courses and congresses in Italy and worldwide, and published numerous scientific articles in national and international journals. In collaboration with Dr C.J. Ruddle, he produced a series of scientific videos called The Endodontic Game, since distributed in Europe, the US, Canada, Australia and Asia.
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Apicectomy of an endodontically compromised central incisor

Drs Georgi T. Tomov & Mutlu S. Turkkan, Bulgaria

The following article presents a case of Er:YAG laser-assisted surgical removal of a fractured endodontic instrument from the periapical region of a maxillary central incisor.

Introduction

Fracture of endodontic instruments in the root canal is one of the most troublesome incidents in endodontic therapy. It is reported that the prevalence of fractured instruments is between 0.5 and 5.0 per cent. Endodontic instruments rarely separate beyond the apical foramen. The fractured segment is a foreign object and might cause inflammation. Moreover, patients often regard the fractured segment as a broken needle and suffer psychologically. Thus, an attempt to remove these objects through surgery is often necessary.

Apicectomy is an alternative approach to surgical endodontic therapy. It entails removing periapical inflammatory tissue, followed by apical resection and retrograde filling of the root canal. Such procedures are performed using a trans-osseous approach. The success rate of the apicectomy procedure is above 91 per cent. Moreover, new techniques are being introduced constantly, with many including the use of Er:YAG lasers.

It is important to recall the principles of endodontic surgery that dictate treatment. The prime considerations may be summarised as follows:

- A thorough appreciation of the surgical anatomy is of primary importance in order to carry out a well-performed procedure. An adequate radiographic investigation must precede the surgery in order to properly assess the lesion and the associated anatomical structures.
- The preferred mucoperiosteal access is through a semilunar incision, which must always be positioned above the lesion and never through the lesion itself.
- The surgeon needs to have both experience and a good surgical technique.
- Associated granulation tissue or more organised periapical pathology must be thoroughly removed.
- The root apex must undergo appropriate resection in order to eradicate the apical tip and any accessory root canals in this region. Wherever possible, the resection level should be coincident with the buccal or labial alveolar bone level.
- It is considered appropriate that a retrograde root canal filling should be performed routinely during apical surgery. The purpose of the retrograde filling is to seal the exposed root canal and prevent leakage of pathogens into the periapical area. Isolation of the root area is vital during this procedure and will enhance a successful outcome.

New techniques, materials and technologies can be used to increase the already high success rate of periapical surgery. Treatment with an Er:YAG laser is considered an alternative that bears many advantages.

Using the Er:YAG laser in apicectomy surgery

Features of Er:YAG laser-assisted surgery with specific regard to apicectomy procedures are:

- The Er:YAG laser has a wavelength of 2,940nm. The prime chromophore of this laser wavelength is water, which makes it appropriate for ablating both hard and soft oral tissue.
- The Er:YAG laser can perform incisions for flap lifting, such as a crestal incision, an intrasulcular or vertical releasing incision, or semilunar incision. The laser produces a wet incision (there is some bleeding).
- Ablation of granulation tissue after raising a flap is efficient with the Er:YAG laser, posing a lower risk of overheating the bone.
- Lasing directly on the bone achieves detoxification of the infected site. Studies have shown that Er:YAG laser energy effects on bone cause bacterial reduction.
- The Er:YAG laser can be used for ablation of alveolar bone tissue—remodelling, shaping and ablation of necrotic bone.
- The Er:YAG laser can be used for root apex resection in contact mode and for preparation of the apex cavity for retrograde filling.
- Although studies into the use of the Er:YAG laser in clinical bone surgery procedures have reported inconclusive subjective advantages in terms of time required, postoperative pain levels or ease of access, histological investigations have demonstrated better levels of early healing of the bone with the laser compared with the surgical bur and piezoelectric surgery.

This article presents a case in which an Er:YAG laser was used successfully to remove an endodontic instrument fractured beyond the apical foramen.

Case report

A 28-year-old female patient came to the practice complaining about periodic episodes of pain associated with the maxillary right central incisor. The patient’s general medical history was uneventful and she was not taking any medication. Upon examination, the tooth had been restored with a porcelain-fused-to-metal crown. Her general level of oral health was good, owing to adequate oral hygiene. In addition, the periodontal condition was good, with no pocketing or bleeding on probing. Periapical radiographic examination showed a fractured instrument (lentulo) beyond the root canal and a radiolucent area around the apical portion of the root canal (Fig. 1). A diagnosis of periapical granuloma due to failure of the orthograde root filling complicated by a fractured instrument beyond the apical foramen was made, and treatment indicated surgical curettage of the area and apicectomy.

Treatment protocol

A fibreless laser system with an operating wavelength of 2,940 nm (LiteTouch, Light Instruments) was employed for this procedure, following the protocol described by Dr A. Reyhanian. Treatment alternatives included the use of a conventional scalpel, curettes and rotary instruments.

The laser operating parameters employed for the various surgical stages were as follows:
- Releasing incision of the flap: contact mode, 200 mJ, 35 Hz; 0.4 × 17.0 mm tip.
- Bone removal to expand the entrance to the apex: non-contact mode, 300 mJ, 35 Hz; 1.3 × 19.0 mm tip.
- Ablation of granulation tissue: non-contact mode, 400 mJ, 15–20 Hz; 1.3 × 19.0 mm tip.
- Resection of the root apex: non-contact mode, 400 mJ, 20 Hz; 0.8 × 14.0 mm tip.
- Retrograde cavity preparation: non-contact mode, 400 mJ, 20 Hz; 0.8 × 14.0 mm tip.

A semilunar incision was made after administering infiltrative anaesthesia. The incision extended from a point approximately to the distal area of the maxillary right lateral incisor to the distal area of the maxillary left central incisor (Fig. 2) and the flap was elevated (Fig. 3). A small fenestration of the labial bone was performed and surrounding bone was ablated in order to expand the entrance to the defect. After the removal of the compact bone, the fractured instrument was exposed and could be removed easily. The next step was granulation tissue removal and bone cavity disinfection (Fig. 5). Using the Er:YAG laser to cut the apex and to prepare the apex cavity for retrograde filling (in non-contact mode) (Fig. 6). The radiograph before treatment (a). The removed separated instrument (b). The radiograph after one year revealed a completely healed bone defect with no signs of bone resorption (c).
After removal of the fractured instrument, the root apex was sectioned. The Er:YAG laser energy produced a smooth, clean resection without visible signs of thermal damage. At the same power setting, the cavity of the apex was prepared for retrograde filling. Finally, the bone defect was shaped and remodelled. The retrograde cavity was sealed with mineral trioxide aggregate (MTA, Fig. 5). MTA has been recommended for root end filling during endodontic therapy and presents advantages such as easy placement, a hydrophilic nature, a lack of toxicity and low solubility. The flap was sutured with a 3/0 silk thread, with careful attention to good primary closure (Fig. 6). The patient was prescribed amoxicillin (500mg/8 hours) for seven days and ibuprofen (600mg/8 hours) for three days. After seven days, the patient was recalled to have the sutures removed. The swelling had resolved and healing was progressing well. After six weeks, the soft tissue had completely healed without complications. The radiographic examination after one year revealed a completely healed bone defect with no signs of resorption. The prognosis was considered excellent (Fig. 7).

Discussion

This case report has described the use of an Er:YAG laser for apicectomy, emphasising the advantages of this laser wavelength in performing an apicectomy versus conventional methods. The use of the Er:YAG 2,940nm laser has been shown to be effective in the surgical ablation of tooth tissue and bone.

Advantages of this modality over conventional rotary instrumentation may include precision, bacterial decontamination, less collateral damage, and tactile stimulation. In addition, although studies have been equivocal, the use of this laser in surgical procedures may result in less fatigue of the surgeon and greater patient acceptance. What has been demonstrated is an enhanced early healing response in bone tissue and a lesser level of post-operative complications.

In addition to these clinical observations, we have studied the apical surface characteristics and presence of dental cracks in extracted single-rooted human incisors, resected 3.5mm from the root apex using the Er:YAG laser, a stainless-steel bur and a diamond-coated ultrasonic tip, respectively, by scanning electron microscopy (SEM, Fig. 8). The SEM images showed that the stainless-steel bur produced significantly smoother resected root surfaces than did the diamond-coated tip and Er:YAG laser. There was no statistically significant difference between the Er:YAG and diamond-coated tip groups. However, the analysis of scores obtained for the cut quality according to the Kruskal–Wallis test revealed no significant differences among the groups. More importantly, in our study, Er:YAG-treated teeth had no cracks after the apical resection, unlike the other two groups. Photomicrographs of the Er:YAG laser group revealed exposed dentinal tubules after resection in contrast with the stainless-steel bur group (a heavy smear layer) and the diamond-coated ultrasonic tip group (a thin smear layer). To sum up, it can be stated that the Er:YAG laser produced better apical root surfaces than did the diamond-coated ultrasonic tip or stainless-steel bur. Within the limitations of this in vitro study, we can also conclude that the diamond-coated tip provoked a larger number of cracks compared with the Er:YAG laser.

Conclusion

The outcome of this clinical case indicates that the use of the Er:YAG laser should be considered an alternative, suitable and useful method for performing an apicectomy. It has been shown to be effective and safe.

contact

Dr Georgi T. Tomov
Head of the Department of Oral Pathology
Faculty of Dental Medicine
Medical University of Plovdiv, Bulgaria
dr.g.tomov@gmail.com
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Laser enucleation of a radicular cyst with the PIPS protocol

Dr Betül Göfteci, Turkey

Introduction

The most frequent odontogenic cyst in tooth-bearing areas is the radicular cyst, also called a periapical cyst. It arises from epithelial cell rests of Malassez in the periodontal ligament as a result of inflammation. Radicular cysts may be seen with irreversible pulpitis, root fracture, periodontal disease and apical periodontitis, and with or without fistulae. The diagnosis is usually made on the basis of anamnesis, clinical investigation and a radiograph or cone beam computed tomography (CBCT) scan. Enucleation is defined as the complete removal of the cyst by separating the cystic lining from the inner bony surface. Although small cystic lesions frequently heal with endodontic therapy only, larger lesions may need additional treatment. Untreated cysts may expand, causing local tissue destruction and deformities.

The treatment of choice depends on the size and location of the lesion, the bone integrity of the cystic wall and the cyst’s proximity to vital structures. Cysts are usually enucleated and removed and the cavity allowed to fill with blood to form a clot. The aim of enucleation of a cyst is to remove all of the cystic tissue, disinfect the area and finally allow the bone tissue to fill the cavity with new bone. The location of the cyst could make these clinical steps difficult to achieve. In addition, the ability to successfully remove the smear layer and bacteria continue to be a challenge in intrabony infections.

The use of the Er:YAG laser is promising for reduced risk of recurrence and improved healing, depending on the ability to disinfect the surgical area and remove the smear layer. Therefore, the aim of using the Er:YAG laser in this study was to achieve atraumatic cleansing of the extraction sockets and cystic cavity, as well as disinfection of the area and removal of the smear layer, during the cyst enucleation for better and faster healing.

Materials and methods

Medical and dental history

A 38-year-old white male presented for dental treatment. He suffered from diabetes, which was under medical control, however. He reported no allergies. The patient complained of a fractured maxillary right molar. Radiographic (CBCT) examination was performed. The radiograph confirmed that teeth #15 and 16 had previously undergone root canal therapy. The patient was diagnosed with a radicular cyst at teeth #15 and 16 below the maxillary sinus (Figs. 1a & b). The treatment plan included extraction of the teeth, enucleation of the cyst without perforating the maxillary sinus, and follow-up treatment.

Treatment

It was planned to follow the extraction of the teeth by irradiation with an Er:YAG laser for removal of granulation tissue in the extraction sockets and enucleation of the cyst. A collagen barrier membrane would be used thereafter to aid healing of the cystic cavity. After extraction, an Er:YAG laser with a wavelength of 2,940 nm (LightWalker, Fotona) was used to irradiate the extraction sockets. First, removal of granulation tissue was performed with a cylindrical tip, using the following parameters: 150 mJ per pulse, 20 Hz, short pulse duration, water spray setting 6 and air spray setting 3 (Fig. 2). A modified PIPS (photon-induced photoacoustic streaming) irrigation protocol was then performed for enhanced removal of residual cystic tissue (Fig. 3a). A quartz PIPS fibre tip of 9 mm in length and 600 µm in diameter was used. The tip, as received from the manufacturer, was tapered and had 3 mm of the polyamide sheath stripped back from its end. The following laser operating parameters were used: 40 mJ per pulse, 15 Hz and 50 µs pulse duration (super-short pulse). The coaxial water spray feature of the handpiece was set to “off”. The tip was placed into the extraction socket and used under constant saline irrigation (Fig. 3b). The coaxial water spray feature of the handpiece was set to “off”. The tip was placed into the extraction socket and used under constant saline irrigation (Fig. 3b). The cyst was enucleated (Figs. 4a–c) and the cystic cavity was checked for residual granulation tissue. Augmentation of the cystic cavity was performed using a collagen barrier membrane and the cavity was subsequently sutured (Figs. 5a–d). After the procedure, a post-operative analgesic and antibiotics were prescribed, and the patient was instructed on continuing care at home.

Results

No complications arose during or immediately after the laser-assisted surgical treatment. Follow-up visits were scheduled at one week, three months and nine months post-operatively. At the first follow-up, the healing process
Fig. 1a & b: Radiographic (CBCT) examination revealed a radicular cyst at teeth #16 (a) and 15 (b). Fig. 2: Removal of granulation tissue from the extraction socket. Figs. 3a & b: Modified PIPS irrigation protocol for cyst enucleation from a deep extraction socket (a). Thirty seconds of PIPS irrigation with saline was followed by a 60-second resting phase and degranulation until successful cyst enucleation was achieved (b). The procedure can be repeated if necessary. Figs. 4a–c: The cyst was successfully enucleated (a & b) from the cystic cavity (c).
appeared uneventful. At the three- and nine-month follow-ups, good complete soft-tissue healing had occurred (Figs. 6a & b). Control radiographs were taken. At the three-month follow-up, hard-tissue healing was progressing naturally (Figs. 7a & b). At the nine-month follow-up, the hard-tissue healing was complete (Figs. 8a & b). The patient was then referred for further dental treatment needs, including implant therapy, and monitoring through follow-up appointments was planned.

Discussion

The adequate treatment of cysts is still a matter of much discussion. Various treatment options have been suggested, depending on the size and location of the cyst. While for large lesions, endodontic treatment is followed by surgical enucleation, some authors have proposed non-surgical management of small lesions. In this case, however, tooth extraction was decided on owing to the enlargement of the cyst, old root canal fillings and a fractured tooth. When cysts are large, they tend to expand the surrounding bone. In many cysts, there is a tendency for the epithelium to separate from the underlying cyst wall. Histopathologically, they typically show a thin, friable wall, which is often difficult to enucleate from the bone in one piece, and have small satellite cysts within the fibrous wall. In this case, the cyst was enucleated from the bone in one piece.

Cysts tend to recur after treatment. The goals of treatment should include the elimination of the potential for recurrence while also minimising the surgical morbidity. There is no consensus on adequate and appropriate treatment for this lesion. Recurrence can occur for several reasons. The first is incomplete removal of the original cyst’s lining. The second is the growth of new cysts from small satellite cysts of odontogenic epithelial rests left behind after the surgical treatment. The third is the development of an unrelated cyst in an adjacent region of the jaws, and this is misinterpreted as a recurrence. It is believed that the two most common reasons for recurrence are incomplete cyst removal and new primary cyst formation. The majority of recurrence cases occur within the first five years after the treatment. Many attempts have been made to reduce the high recurrence rate by improved surgical techniques. The aim of using the Er:YAG laser in this study was to achieve cleansing of the extraction sockets and cystic cavity, as well as smear layer removal, during the cyst enucleation for healing and no recurrence. It is important to remember that microbes initially cause the lesion and continue to maintain the immune response and, thus, the apical periodontitis. The time that is required for healing in these cases ranges from eight to 14 months. Follow-up on the process of healing should be done every six months for a duration of at least four years.

In this specific case, it had been decided on the use of a PIPS tip and a modified PIPS protocol for enhanced removal of residual cystic tissue and the smear layer from the surrounding bone. The PIPS protocol has previously been used for enhanced root canal therapy. Cleaning and disinfection of the root canal system are some of the most important goals in endodontic therapy. Conventional endodontic treatment is not fully effective owing to microbial colonisation of dentine of the root canal walls in premolars and molars. The PIPS technique uses low energy levels and short microsecond pulse rates (50 µs) to generate high peak power. Each pulse interacts with the water molecules, creating successive shock waves that lead to the formation of a powerful streaming fluid and facilitate 3D movement of the irrigation solution. Using the Er:YAG laser with sub-ablative parameters (average power of 0.3W and 20mJ at 15 Hz) has proven to be an effective irrigant agitation technique and an
Effectiveness technique for removing the smear layer in endodontic treatment. When the laser was activated in a limited volume of fluid, the high absorption of the Er:YAG wavelength in water and the short pulse duration (50 µs) that was used resulted in a photoacoustic phenomenon in the extraction sockets. The resulting cavitation was expected to effectively remove the smear layer and residual tissue tags and potentially decrease the bacterial load within the bone tubules, as previously observed in hard tissue. In this case, by using lower sub-ablative energy, combined with a short pulse duration, and restricting the placement of the fibre tip to within the coronal portion of the extraction sockets, undesired thermal effects on the tissue were also avoided.

Conclusion

This case report presents successful surgical management and healing of a large cyst with an Er:YAG laser using a modified PIPS protocol. Easy-to-select operating modes and an advanced laser beam delivery system enhanced the precision and performance of the laser treatment for optimal clinical efficacy.

Contact

Dr Betül Göfteci
MedicaDent Dental Clinic Istanbul
Mühürdar Cad. 69/1
34710 Kadıköy/Istanbul, Turkey
Phone: +90 216 4149988
kadikoy@medicadent.com

Figs. 7a & b: The CBCT scan of teeth #15 (a) and 16 (b) after three months revealed natural hard-tissue healing. Figs. 8a & b: The CBCT scan at the nine-month follow-up revealed that hard-tissue healing was complete.
The primary objective of endodontic treatment is to seal the root canal reliably in the long term to effectively prevent reinfection and the reintrusion of microorganisms. Modern obturation materials also provide useful bioactive properties and thus promote the regeneration of bone and dentinal tissue. The following discussion focuses on which biochemical properties the ideal filling material should offer in endodontics and why cement does not always equal cement.

In medicine, biomaterials are natural or synthetically produced materials that come into direct contact with biological tissue when used in the human body. Of particular interest are the interactions that occur between the body's own structures and the material used in each case. The observed processes can be of a chemical, physical or biological nature—and it is particularly exciting to know whether they occur spontaneously and therefore rather randomly, or if they can even be used specifically for therapeutic success. Given the large number of filling materials available on the market today, it is more important than ever to know the difference between biocompatibility and bioactivity and to understand which compounds trigger the desired catalytic effects and why.

Biocompatibility versus bioactivity

Biocompatibility is the basic requirement in dentistry for the use of a material that remains in the body for a long time. The occurrence of toxic symptoms or other toxic side effects would be more than counter-productive. Bio-inert materials are substances that do not initiate any significant reaction of the surrounding tissue.

In practice, surgery is often performed with certain threshold values which may not be exceeded for bio-inert substances because internal implants can, for example, at least cause some form of encapsulation in the body even if they do not provoke direct interaction. Corrosion resistance and thermal stability are, of course, prerequisites for bio-inert materials. Good examples for the use of a bio-inert material in dentistry would be composite veneering systems in which plastic shells are fixed to the dentine with an identical high-performance composite without causing the broken or damaged tooth to grow again. The opposite are essentially biodegradable dental materials such as completely biodegradable wound dressings made of gelatine and colloidal silver.

Bioactivity, however, promotes the body's own regeneration potential. Since the 1960s, materials research has been intensively concerned with substances that actively support natural regeneration and additionally stimulate the formation of new dentinal tissue. At the same time, such processes must, of course, take place within a manageable framework and have well-defined effects, even under non-laboratory conditions. True bioactivity plays a new practical role in connection with endodontic obturation materials and thus complements the actual functions of the material.
MTA from the do-it-yourself store?

The classic product among bioceramic materials in the root canal is clearly mineral trioxide aggregate (MTA). This mixture of various calcium silicates and sulphates has been used successfully in dentistry since the 1990s. Bismuth oxides were added to increase radiopacity. The result was a reproductive material which, among other things, was suitable for the repair of smaller defects, as it promoted the formation of tertiary dentine.

Unfortunately, it not only caused discoloration but also proved to be relatively difficult to handle: insertion into the canal with the appropriate consistency required quite some practice. Furthermore, curing times of several hours for some MTA products are often not really practicable in everyday routines. In addition, this longish time span comes quite literally at a relatively high price. Resourceful minds were therefore quick to look for a cost-effective alternative. After a meticulous review of more than 50 different studies, Brazilian scientists came to the astonishing conclusion that MTA had to be nothing more than slightly modified, high-purity Portland cement. Both materials featured similar biological and mechanical properties and exhibited similar effects when used in animal experiments. The technical characterisation of the materials also showed striking similarities. Particularly in emerging economies such as Brazil, rumours spread that dentists with price-sensitive customers had been tempted to augment their stocks with samples from local do-it-yourself stores. Although this approach may have proved luring with quite attractive prices, the radiographic view of the construction product would probably leave much to be desired—not to mention the legal and medical acceptability of such an idiosyncratic off-label use.

Bioglass for the repair of bone defects

Another material for endodontic filling therapy is bioglass. Basically, bioglass consists of silicon oxide, calcium oxide, sodium oxide and phosphorous oxide. Already back in 1969, the American scientist Dr Larry L. Hench discovered that the generally well-tolerated material has the ability to bind to living bone material. Today, its osteoinductive effect is used specifically to repair smaller bone defects. Given the right conditions, the material initially induces a high pH value. This potentially helps to contain the colonisation or renewed growth of microorganisms. The search for a versatile obturation material resulted in the appealing idea of employing the repair potential of bioglass in a cleverly combined material that has regenerative capabilities and, of course, achieves its main task: the effective filling and safe sealing of the cleaned cavity in the root canal for sustainable patient care.

Gutta-percha as an indispensable basis

Polyisoprene, or gutta-percha, is well known to Swiss dental specialist COLTENE. For more than 100 years, high-quality consumables and working aids for dentists and dental technicians have been leaving the production lines in the company’s own German production facility in Langenau. Gutta-percha is also refined for dental use in a manufacturing process developed in-house. Zinc oxide facilitates the processing of gutta-percha, and the inhibition test demonstrates that it can also prove useful in combating bacteria. The addition of barium sulphate increases radiographic opacity, and waxes increase flexibility. The flexible filler is then dyed pink according to the preferences of practice teams, the reason being that originally the latex of the tropical trees is rather beige and visually unattractive. Gutta-percha has long been established as an obturation material in endodontics, as it embodies all the properties a long-lasting root canal filling material should have:

- It is well tolerated, and above all, it is bio-inert.
- It can efficiently seal the root canal in both a lateral and vertical direction.
– It is volume-stable.
– It can withstand conditions in the root canal for many years.

The GuttaFlow obturation material from COLTENE is produced with gutta-percha in powder form using a silicone-based sealer. Various vitality studies have demonstrated the high biocompatibility of GuttaFlow. Cytotoxicity of various commercially available obturation materials has been detected in periodontal stem cells. The combined preparation of GuttaFlow bioseal has shown significantly better tissue compatibility and significantly higher proliferation rates. The predecessor version, the traditional sealer RoekoSeal (also from COLTENE), is often used as a zero standard in international studies, as no negative effects of the material have been observed in the laboratory and in clinical use.

Hydroxyapatite crystals— the regeneration elements

Many years of experience, as well as the close proximity to their production process, allowed the endodontic experts at COLTENE to develop an obturation material that effectively combines the reliability of cold liquid gutta-percha with the regenerative power of bioglass. True to the current quality promise of “Upgrade Dentistry” of the innovation-driven company, an endodontic three-in-one cold filling system with excellent flow properties has now been developed. As with the proven GuttaFlow 2 system, GuttaFlow bioseal combines fluid gutta-percha with silicone-based sealer and additional bioceramics at room temperature (Fig. 1).

Owing to its bioactive properties, the easy-to-apply material can initiate biochemical processes in situ that additionally support regeneration in the root canal. In detail, this works as follows: after curing, GuttaFlow bioseal provides natural repair elements such as calcium and silicates under certain conditions. Upon contact with body fluids, hydroxyapatite crystals are formed on the surface. As natural triggers, these crystals stimulate the reconstruction of bone and dentinal tissue (Fig. 2). The use of this catalytic effect can serve as a fallback for critical situations, in addition to effectively sealing the canal.

Optimum radiographic visibility is naturally a given for this dental product (Figs. 3a & b). In addition, the easy-flowing filling material impresses with its uncomplicated handling compared with MTA. The obturation material is applied using a 5ml automix syringe and has a processing time of only approximately five minutes and a curing time of 12 to 16 minutes.

Solubility

Another advantage that clearly speaks in favour of using such a sealer combination is the scientifically proven durability of the material. GuttaFlow bioseal activates the bioactive components solely on the surface and with the body’s own fluids. Pure water cannot promote the formation of crystals. Gutta-percha and the silicone-based sealer are insoluble by nature and therefore automatically slow down a possible solubility process. This does not give rise to the question as to whether solubility progresses faster than the repair of dentine with higher fluid entrapment. In laboratory tests with acid, it was demonstrated that a GuttaFlow filling remains completely intact even after the complete tooth has already been successfully dissolved (Fig. 4). The solubility of this three-in-one combination product is therefore rather low at approximately 0.8 per cent. This is mainly due to the inert properties of sealer and gutta-percha.

Furthermore, the high density in the root canal is due to the thixotropic formulation of the material. Viscosity decreases under pressure and the material can therefore flow into even the smallest lateral canals and isthmuses. In addition, the material combination does not shrink, but even expands slightly. The resulting retention thus leads to a reliable marginal seal.

A closer look at the various bioceramic obturation materials on the market reveals not only considerable differences in price but also the difficulties of testing them in the laboratory according to ISO standards. It is difficult to control and verify parameters such as moisture and oxygen in the root canal.

Obturation material successful in animals

The new combination material builds on many years of experience with predecessor materials and expands the
horizon not only in a regenerative direction. A look outside the box into veterinary medicine reveals why dental specialists in veterinary medicine in particular are increasingly relying on the novel root canal filling material. Rare large and wild animals are often subject to strict breeding and species protection programmes, but their dental treatment poses a particular challenge for zoos. Unfortunately, the animals only tolerate general anaesthesia very poorly, making treatment almost impossible. Here, too, endodontic experts benefit from the bioactivity of a filler. At the same time, the actual treatment time is shortened by the necessity of administering a short-acting anaesthetic. The safe and fast application of a flowable material is of major advantage (Fig. 5). The transferability of these empirical values into one’s own practice is obvious: human patients also benefit from rapid treatment procedures and one-off successful root canal therapies.

Outlook
The central task of a reliable endodontic obturation material remains the safe 3D sealing of the entire root canal system. Gutta-percha-based materials have demonstrated excellent, reproducible results for many years in this area. In addition, bioactive three-in-one filling systems support regeneration in the root canal by forming hydroxyapatite crystals upon contact with body fluids. Current products with bioglass are a cost-effective alternative and convince by their good tissue compatibility and easy handling. In the long term, the desire in endodontics for chairside individual 3D filling of each individual root canal remains.

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

about
Dr Barbara Müller studied agricultural biology at the University of Hohenheim in Stuttgart in Germany and obtained a Master of Science from the University of Georgia in the US. In 1993, she completed her PhD at Ulm University in Germany. Between 1996 and 2010, Dr Müller held the position of research and development manager at COLTENE, and she has been involved in the development of products such as RoekoSeal, GuttaFlow and HyFlex CM nickel-titanium files. Since 2011, she has been head of the company’s endodontics product segment. She has been a guest speaker at numerous events hosted by European dental and endodontic societies.
Achieving a sufficient disinfection of the root canal system is a procedure that requires multiple steps. Among these, irrigation plays a key role, helping mechanical instruments to remove pulp remnants, debris and the smear layer from the root canal walls. Mechanical instrumentation alone cannot remove the totality of bacteria from the root canal system, and research published in the literature has demonstrated that untreated canal areas for individual canals can range from 10 to 50 per cent.1–5 These areas may shelter pulp remnants and bacteria, jeopardising the outcome of the endodontic treatment6 and leading to apical periodontitis. 7 Irrigation of root canals works together with mechanical instrumentation in order to improve the removal of bacteria, pulp tissue, the smear layer and debris from the root canal system,8 thus reducing the risk of post-treatment disease.

Sodium hypochlorite has antimicrobial and tissue-dissolving abilities, but its capability of eliminating bacteria depends on several factors, among which penetration along the full length of the canal and fluid exchange play an important role.6, 9 The anatomy of the root canal system, the irrigant delivery system, the depth of placement, the fluid properties and the volume of the irrigant affect its flushing action.10 The anatomical complexity of teeth has widely been investigated in the literature, and the root canal system is particular of interest because of its anatomy and variability (Fig. 1).11

In vitro and ex vivo studies have shown the presence of bacteria in the dentinal tubules and cementum even after treatment, emphasising that the goals of total disinfection of the canal may not be achieved by cleaning and shaping only.12 The filling of the prepared root canal is a further step in endodontic therapy, preventing bacteria from reinfesting the tooth and the periapex. The majority of obturating systems in endodontic therapy are composed of a core material and a sealer. The sealer should not only fill the gaps between the core material and the root canal wall, but also fill the surface irregularities of the root canal system (such as lateral canals and isthmuses) in order to achieve a tight seal (Figs. 2a & b).13 To overcome the problem of bacterial persistence in the root canal system, the market has progressively developed filling materials with antibacterial properties. The antibacterial nature of sealer is valuable because of the higher percentage of facultative anaerobes in failed root canal cases. Several resin-based and MTA-based compositions appeared, claiming to be able to destroy the bacteria left in the root canal dentine; nevertheless, the literature showed that antimicrobial sealers (above all, resin-based sealers) are more effective when freshly mixed and their activity reduces after setting12 and they thus cannot be relied on to prevent reinfestation over time.

Achieving good instrumentation and cleaning of the root canal system is more difficult when curved canals have to be treated. Their anatomy can represent a problem for the penetration of instruments and can reduce their efficiency. The evolution of instruments used in the shaping of the canal system with the introduction of engine-driven nickel-titanium (NiTi) files brought about an improvement in the cleanliness of the root canal walls with respect to manual instrumentation, but a high percentage of the surface was still untouched.14–16 Moreover, mechanical instrumentation is not able to remove all of the smear layer deposited on the root surface, especially in the apical third or in the case of complex anatomies (Figs. 3a–d).11
A recent review by Li et al. clearly states that it is important to realise that no filling material or technique can compensate for inadequate asepsis and disinfection procedures. For this reason, achieving good disinfection of the root canal system has to be a major objective for the clinician, particularly in curved canals.

The anatomy of teeth can make preparation extremely tricky, and mechanical preparation cannot reach all areas of the root. Irrigants too can have difficulty penetrating into narrow spaces, and the difficulty in reaching the most apical region of the canal with large volumes of fresh irrigant may result in poorer performance during cleaning. The most common method for delivery the irrigating solution into the prepared canals is by means of a syringe and needle, according to general guidelines in order to maximise irrigation efficiency and avoid extrusion of irrigant into the periapical tissue. The majority of irrigation needles are made from steel and this material is not able to follow the anatomy of the root canal, particularly when curves are present. Consequently, the needle stops against one of the canal walls, decreasing the rate of fresh irrigant reaching the apical third and increasing the shear stress on the canal wall.

Endodontic irrigation benefits from the use of 5 ml syringes with Luer lock attachments that help the clinician work safely and with a constant flow. The choice of needle is a function of the diameter of the root canal; the needle has to be positioned within 1 mm from the working length, but it does not have to rub against the walls of the root canal (to decrease the risk of extrusion). The needle diameters recommended in endodontics are from 27 gauge to 30 gauge. They are sufficiently thin to be inserted into the root canal and they provide an irrigant flux ranging from 0.19 ml/s to 0.09 ml/s. Moreover, they may result in better exchange and cleaning.

Needles should be designed with dedicated tips and can be notched or side-vented. These shapes generally guarantee a laminar-controlled flow of the irrigating solution and permit safe placement of the tip in the apical third, because the fluid can flow towards the coronal part of the root. It has to be considered that the more violent the flow is, the greater the risk of extruding debris into the periapical tissue, and that open-end needles extrude more product than side-vented needles do. It also has to be said that the further the needle is from the working length, the lower the flux is.

Wall roughness does not affect laminar flow in the middle and coronal thirds of the canal; conversely, it increases the resistance when the flow is turbulent, modifying the flow pattern. The shear stress pattern on the canal wall decreases as needles move away from the working length, but the area affected by high shear stress becomes larger. This area surrounds the tip of the side-vented needle, and maximum shear stress is concentrated on the wall facing the needle outlet, while high stress is concentrated apically when an open-ended flat needle is used. The pressure developed at the apical foramen is higher with flat needles than with side-vented needles at the same depth.

Figs. 3a–d: Curved canals are challenging to shape, clean and fill. Fig. 4: The peculiar back-to-back side-vented design helps improve safety and efficiency of irrigation.

Figs. 5a–c: The flexible tip improves the ergonomics of the irrigation phase and allows rinsing of the canal system in teeth that present complicated anatomies.
Another point to be considered is that the irrigating solution needs to be replaced to maintain its efficiency; thus, a sufficient flow rate has to be established within the root canal. In order to reach this goal, the development of turbulent flow is the best way to achieve efficient irrigant exchange.26 A simple way to create a turbulent irrigant flow within the root canals is via the push–pull technique: alternating positive and negative pressure on the plunger of the syringe helps create a turbulence that promotes the irrigant exchange.

It has been demonstrated that using a syringe to inject the irrigant into the root canals, unfortunately, is not sufficient to achieve good disinfection,28 because irrigant exchange beyond the tip of the needle is limited with a conventional needle. The air trapped in the apical part of the root canal during irrigation (vapour lock effect) might also decrease the exchange of irrigants in this area, reducing the efficiency of irrigation.29 For this reason, the literature has reported the need for activation of the irrigating solution. Curved canals represent a challenge for the action of irrigants, because the fluid penetration is not as effective as in straight canals. For this reason, activating the irrigant is advised to achieve superior cleaning of these areas.22 According to Cunningham and Joseph30, and Basrani and Haapasalo,31 increasing the temperature of the solution above 37 °C increases the anti-microbial activity of sodium hypochlorite. The temperature of the irrigant can be increased by preheating or agitation.

Technological advancements have influenced the agitation of irrigants, in particular for the final rinse before filling. The techniques available include ultrasonic activation, sonic activation and dedicated devices which generate negative pressure through a micro-cannula inserted to the working length, facilitating the apical flow of the irrigant.31 It seems that ultrasonic activation of the irrigant is the most studied and used method to reach this goal, because it increases the temperature of the solution, and by creating turbulence, it improves its cleaning efficiency in the apical third by 5 per cent and generates a continuous solution exchange.32

Technology has also improved microinjection techniques. For example, polymeric needles (e.g. IrriFlex, Produits Dentaires) have been developed that are able to guarantee both safety and efficiency of root canal cleaning owing to an innovative back-to-back side-vented design that improves the fluid dynamics in the canal (Fig. 4).

Clinicians need cleaning to be effective, particularly in the final rinse of the root canal system in teeth that present difficult anatomies (Figs. 5a–c). As reported before, steel needles have significant drawbacks in curved canals because they have the tendency to block and engage the external walls of the canal (Fig. 6). However, using a 30 gauge soft polypropylene needle allows superior flexibility compared with steel or even NiTi, following the anatomy of the root to the working length (Fig. 7). Technological advancements are helpful for achieving superior cleaning of the root canal system, ensuring safe and efficient action of the irrigating solutions.

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

about

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 restorative dentistry and endodontics books. Dr Cerutti has spoken at national and international congresses on post-endodontic restoration and aesthetic reconstruction of teeth. She is a reviewer for international journals such as the Journal of Adhesive Dentistry, European Journal of Paediatric Dentistry and Biomaterials.

Dr Cerutti is a member of the Italian Society of Endodontics and served as editorial coordinator of the Italian Journal of Endodontics from 2008 to 2011. She is a silver member of Style Italiano Endodontics.
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The use of pre-mixed bioceramic materials in endodontics

Dr Gilberto Debelian, Norway & Dr Martin Trope, USA

Introduction

Microbes within the root canal system are the cause of apical and periradicular periodontitis (endodontic disease). The absence of microbes ensures that apical periodontitis of endodontic origin does not occur. Therefore, the aim of endodontic treatment is to prevent microbial contamination of the root canal system and/or to remove enough microbes to ensure clinical and radiographic success.

Root canal therapy is divided into the microbial control phase (instrumentation, irrigation and intracanal medication) followed by the filling phase (root and top filling). With both antimicrobial and sealing properties, pre-mixed bioceramic materials are one of the few materials available in endodontics that contribute to both critical phases for endodontic treatment success.

Bioceramics

Bioceramics are ceramic materials specifically designed for medical and dental use. During the 1960s and 1970s, these materials were developed for use in the human body for applications such as joint replacement, bone plates, bone cement, artificial ligaments and tendons, blood vessel prostheses, heart valves, skin repair devices (artificial tissue), cochlear replacements and contact lenses. Bioceramics are inorganic, nonmetallic, biocompatible materials that include alumina, zirconia,
bioactive glass, composites, hydroxyapatite, resorbable calcium phosphates, and radiotherapy glasses. They are chemically stable and noncorrosive, and interact well with organic tissue.

Bioceramics are classified as:

– bioinert (noninteractive with biological systems);
– bioactive (durable in tissue that can undergo interfacial interactions with surrounding tissue); and
– biodegradable, soluble or resorbable (eventually replace or are incorporated into tissue).

There are numerous bioceramics currently in use in dentistry and medicine. Alumina and zirconia are bioinert ceramics used in prostheses. Bioactive glass and glass-ceramics are available for use in dentistry under various trade names. In addition, porous ceramics such as calcium phosphate—based materials have been used for filling bone defects. Some calcium silicates (mineral trioxide aggregate [MTA], ProRoot MTA Root Repair, DENTSPLY Tulsa Dental Specialties) and bioaggregates (DiaRoot BioAggregate, DiaDent) have also been used in dentistry as materials for root repair and for apical root filling.

Bioceramics in endodontics

Bioceramic materials used in endodontics can be categorized by composition, setting mechanism and consistency. There are sealers and pastes, developed for use with gutta-percha, and pastes, designed for use as the sole material, comparable to MTA. Some are powder-liquid systems that require manual mixing. The mixing and handling characteristics of the powder-liquid systems are very technique-sensitive and produce considerable waste. Pre-mixed bioceramics require moisture from the surrounding tissue to set. Pre-mixed sealer, paste and putty have the advantage of uniform consistency and lack of waste. These pre-mixed bioceramics are all hydrophilic.

Fig. 4: A representative radiograph of a root-filled tooth with BC Sealer hydraulically moved with the gutta-percha point. Note that the cold hydraulic technique results in lateral canal puffs similar to with the warm vertical technique. Fig. 5: Molar roots filled with BC Sealer cut at different distances from the apex (0.5, 1.5 and 3.0 mm). One gutta-percha point is used as a plugger to move the sealer using hydraulic pressure. Note that the irregularities are very well filled with the sealer.
Endodontic bioceramics are not sensitive to moisture and blood contamina
tion and therefore are not tech
ique-sensitive. They are dimensionally stable and expand slightly. When set, they are hard, allowing full compaction of a final restoration, and they are insoluble over time, ensuring a superior long-term seal. When setting, the pH is above 12 owing to the hydration reaction, which first forms calcium hydroxide and then dissociates into calcium (Ca\(^{2+}\)) and hydroxyl ions (Figs. 1a & b). Therefore, when unset, the material has antibacterial properties. When fully set, it is biocompatible and even bioactive. When bioceramic materials come into contact with tissue fluid, they release calcium hydroxide, which can interact with phosphates in the tissue fluid to form hydroxyapatite (Fig. 1c). This property may explain some of the tissue-inductive properties of the material. For the reasons above, these materials are recommended for pulp capping, pulpotomy, perforation repair, root end filling, obturation of immature teeth with open apices, and sealing of root canal fillings of mature teeth with closed apices.

Available bioceramic materials in endodontics

There are several bioceramic materials and brands available in the dental market today. The most popular type used in endodontics are listed below:

**Mineral trioxide aggregate**

Few clinicians realise that original MTA is a classic bioceramic material with some heavy metals added. MTA is one of the most extensively researched materials in the dental field. It has the properties of all bioceramics; that is, it has a high pH when unset, is biocompatible and bioactive when set, and provides an excellent seal over time. It has some disadvantages, however. It requires mixing, resulting in considerable waste, is not easy to manipulate, and is difficult to remove. Clinically, both gray and white MTA stain dentine, presumably owing to the heavy-metal content of the material or the inclusion of blood pigment while setting. Finally, MTA is difficult to apply in narrow canals, making the material poorly suited for use as a sealer together with gutta-percha. Efforts have been made to overcome these shortcomings with new compositions of MTA or with additives. However, these formulations affect MTA’s physical and mechanical characteristics.

**Biodentine**

Biodentine (Septodont) is considered a second-generation bioceramic material. It has properties similar to those of MTA and thus can be used for all the applications described above for MTA.

Its advantages over MTA are that it sets in a shorter period (approximately 10 to 12 minutes) and it has a compressive strength similar to that of dentine. A major disadvantage is that it is triturated for 30 seconds in a preset quantity (capsule), making waste inevitable, since in the vast majority of endodontic cases, only a small amount is required.

**Endodontic pre-mixed bioceramics**

In 2007, a Canadian research and product development company (Innovative Bio-Ceramix) developed a pre-mixed, ready-to-use calcium silicate-based material, iRoot SP injectable root canal sealer. Since 2008, these endodontic pre-mixed bioceramic products have been available in North America from Brasseler US as EndoSequence BC Sealer, EndoSequence BC RRM (Root Repair Material, a syringable paste), and EndoSequence BC RRM Fast Set Putty (Fig. 2). Recently, these materials have also been marketed as TotalFill BC Sealer, TotalFill BC RRM Paste and TotalFill BC RRM Putty/Fast Set Putty (Fig. 3) by FKG Dentaire. All three forms of bioceramic are similar in chemical composition (calcium silicates, zirconia, tantalum pentoxide,
calcium phosphate monobasic and fillers), and they have excellent mechanical and biological properties and good handling properties. They are hydrophilic, insoluble, radiopaque and aluminium-free, have a high pH, and require moisture to set and harden. The working time of the BC Sealer and BC RRM is more than 30 minutes, and the setting time is four hours under normal conditions, depending on the amount of moisture available. The recently introduced TotalFill BC RRM Fast Set Putty has all the properties of the original putty, but with a faster setting time (approximately 20 minutes). RRM putties and paste are recommended for perforation repair, apical surgery, apical plugging and vital pulp therapy. Pre-mixed BC Sealer is the only pure medical-grade bioceramic product available as a sealer for endodontic obturation. It has the same basic chemical composition as the other pre-mixed bioceramic products, but it is less viscous, which makes its consistency ideal for sealing root canals. It is used with a gutta-percha point with a surface impregnated with a nanoparticle layer of bioceramic. The gutta-percha is used primarily as the delivery device (plugger; Fig. 4) to allow hydraulic movement of the sealer into the irregularities of the root canal and accessory canals (Fig. 5).

Interestingly, when the taper is not excessive and the gutta-percha point is used primarily as a plugger to move the sealer into the canal irregularities and accessory canals, a radiographic image similar to that of the classical vertical condensation technique is often seen (Fig. 6). In addition, its surface bond to the sealer eliminates a critical pathway for coronal leakage of microbes if the coronal restoration has a defective seal. The gutta-percha also is used as a pathway for post-preparation or for retreatment if necessary.

Properties of the bioceramic sealer and potential changes in root filling technique:

1. The bioceramic sealer is highly hydrophilic and thus the natural moisture in the canal and tubules is an advantage, unlike most other sealers where moisture is detrimental to their performance.

2. When unset, the bioceramic sealer has a pH of above 12. Thus, its antibacterial properties are similar to those of calcium hydroxide. Setting is dependent on physiological moisture in the canal; therefore, it will set at different rates in different environments, but since it has a high pH, any delay in setting can be argued as a benefit.

3. The sealer does not shrink, but expands slightly, and is insoluble in tissue fluid (Fig. 7). Setting is dependent on physiological moisture in the canal; therefore, it will set at different rates in different environments, but since it has a high pH, any delay in setting can be argued as a benefit.

4. If used with a gutta-percha point that is impregnated and coated with nanoparticles of bioceramic, as suggested, it will bond to the core point, thus eliminating the gap between the core and sealer.

The properties listed above, particularly in the presence of a sealer that does not shrink and is insoluble in tissue fluid, should change the long-held rule that in root fillings the core material should take up as much space as possible in order to mask the shortcomings of the sealer and by keeping the sealer as thin as possible. In fact, if it were possible to fill the canal in a homogeneous way, the need for a core material at all is questionable.

Studies on endodontic pre-mixed bioceramic materials

To date, more than 70 studies have been performed on pre-mixed endodontic bioceramic materials. The vast majority of these studies have shown that the properties conform to those expected of a bioceramic material and are similar to those of MTA.

Biocompatibility and cytotoxicity

Several in vitro studies report that BC materials display biocompatibility and cytotoxicity that are similar to those of MTA. In comparison to AH Plus (Dentsply Sirona) and Tubli-Seal (Sybron Endo), BC Sealer showed a lower cytotoxicity. On the other hand, one study concluded that BC Sealer remained moderately cytotoxic over the six-week period and osteoblast-like cells had reduced bioactivity and alkaline phosphatase activity compared with MTA and Geristore (DenMat).
A recent study comparing the results of apicoectomies done with MTA or bioceramic putty in dogs showed the bioceramic putty to be slightly better than the MTA, presumably owing to its superior handling properties.35

pH and antibacterial properties
BC materials have a pH of 12.7 while setting, similar to calcium hydroxide, resulting in antibacterial effects.36 BC Sealer has been shown to exhibit a significantly higher pH than AH Plus37 for a longer duration.38 Alkaline pH promotes elimination of bacteria such as Enterococcus faecalis. In vitro studies have reported that Endo Sequence BC RRM produced a lower pH than white MTA in simulated root resorption defects,39 and EndoSequence BC RRM, EndoSequence BC RRM Fast Set Putty and MTA had similar antibacterial efficacy against clinical strains of E. faecalis.40

Bioactivity
Several studies evaluated bioactivity. Exposure of MTA and EndoSequence BC RRM Fast Set Putty to phosphate-buffered saline resulted in precipitation of apatite crystalline structures that increased over time, suggesting that the materials are bioactive.41 iRoot SP exhibited significantly lower cytotoxicity and a higher level of cell attachment than did MTA-Fillapex (Angelus), a salicylate resin-based root canal sealer containing MTA particles.42 EndoSequence BC Sealer had a higher pH and greater Ca\(^{2+}\) release than did AH Plus43 and was shown to release fewer Ca\(^{2+}\) ions than did Biodentine and White MTA.44

Bond strength
A number of studies evaluated bond strength. One study reported that iRoot SP and AH Plus performed similarly, and better than EndoREZ (Ultradent) and Sealapex (SybronEndo).44 Another study found that iRoot SP played the highest bond strength to root dentine compared with AH Plus, Epiphany and MTA-Fillapex, irrespective of moisture conditions.45 In a push-out test, was similar to AH Plus and greater than MTA-Fillapex.46 When iRoot SP was used with a self-adhesive resin cement, the bond strength of fiber posts was not adversely affected.47 Smear layer removal had no effect on the bond strengths of EndoSequence BC Sealer and AH Plus, which had similar values.48 The presence of phosphate-buffered saline within the root canals increased the bond strength of EndoSequence BC Sealer/gutta-percha at one week, but no difference was found at two months.49 Because of the low bond values in these studies, it is doubtful that any of these findings are clinically significant.

Resistance to fracture
iRoot SP was shown in vitro to increase resistance to the fracture of endodontically treated roots, particularly when used with bioceramic-impregnated and coated gutta-percha cones.50 Fracture resistance was increased in simulated immature roots in teeth with iRoot SP51 and in mature roots with AH Plus, EndoSequence BC Sealer and MTA-Fillapex.52 Similar results were reported for EndoSequence BC Sealer and AH Plus Jet sealer (Dentsply Sirona) in root-filled single-rooted premolars.53

Microleakage
Microleakage was reported to be equivalent in canals obturated with iRoot SP with a single-cone technique or continuous wave condensation and in canals filled with AH Plus sealer with continuous wave condensation.54 A recent study showed the superior sealing ability of EndoSequence BC RRM Fast Set Putty compared with gray MTA.55

Solubility
High levels of Ca\(^{2+}\) release were reported from iRoot SP, MTA-Fillapex, Sealapex and MTA Angelus (Angelus), but not AH Plus. Release of Ca\(^{2+}\) ions is thought to result in higher solubility and surface changes.56 However, the study tested the materials according to ANSI/ADA
specification No. 57, which is not designed for pre-mixed materials that require only the presence of moisture to set. This could be the reason for the difference in findings in this study and in vivo observations.

**Retreatment**

Removal of EndoSequence BC Sealer and AH Plus were comparable in a study comparing hand instruments and ProTaper Universal (Dentsply Sirona) retreatment instruments. None of the filling materials could be removed completely from the root canals, however. Microcomputed tomography showed that none of the retreatment techniques completely removed the gutta-percha and iRoot SP sealer from oval canals.

**Clinical studies**

A randomised clinical trial evaluated iRoot BP and white ProRoot MTA Root Repair as direct pulp capping materials. The study evaluated clinical signs and symptoms and histological pulp reactions, such as inflammation and mineralised bridge formation. No significant differences were found in pulpal inflammation, or in the formation or appearance of a hard-tissue bridge. However, clinical sensitivity to cold was significantly less for teeth treated with MTA (P < 0.05). All teeth formed a hard-tissue bridge, and none of the specimens in either group had pulpal necrosis.

**Indications and case examples**

The following section will illustrate endodontic clinical cases where the pre-mixed bioceramic material was used:

**Indirect and direct pulp capping and pulpotomy of carious exposure**

Historically, endodontists have not recommended vital pulp therapy on teeth where caries has exposed the pulp. The results of this procedure have showed poor results. However, these studies used calcium hydroxide as the pulp capping agent and amalgam as the coronal restoration; therefore, if the amalgam leaked, the calcium hydroxide base would wash out. This resulted in calcified canals—if the pulp survived—or necrotic pulps with infection and apical periodontitis. New studies and case series observations have shown that if the base used is antibacterial (such as calcium hydroxide), sets hard and—most critically—seals well, both indirect and direct pulp capping and pulpotomy procedures have a very good chance of a successful outcome. In relatively young patients, these should be the treatment of choice.

**Case 1: Direct pulp capping**

Figure 8 shows the preoperative radiograph of an apparently carious exposure on tooth #46 of a 20-year-old male patient. A diagnosis of reversible pulpitis was made based on the history and clinical examination. After anaesthesia and caries removal, the exposure was seen and covered with EndoSequence BC RRM Fast Set Putty. After the BC base had fully set, a bonded resin was placed and a post-operative radiograph taken. At the six-month follow-up visit, the tooth was asymptomatic and tested vital. Radiographically, no signs of pathology were noted.

Figs. 11a–f: Pre-op radiograph (a). After apicoectomy and retroprep (b). Use of a BC putty over a retroprep cavity filled with BC Sealer (c). Final placement and verification of BC putty retrofill (d). Immediate post-op radiograph: note the presence of BC Sealer along the post toward the coronal part (e). One-year follow-up with advanced periapical healing (f). (Images courtesy of Dr Gilberto Debelian)
Case 2: Pulpotomy

In this case (Fig. 9), the tooth tested vital, but showed clinical signs of irreversible pulpitis. Treatment with a full pulpotomy was chosen to improve the possibility the remaining pulp would survive and remain healthy. The preoperative radiograph showed extensive caries in the tooth and a slightly widened apical periodontal ligament. A full pulpotomy was performed using EndoSequence BC RRM Fast Set Putty. After the putty had set, a coronal restoration was placed, and an immediate post-operative radiograph was taken and viewed. At the one-year follow-up, the tooth was asymptomatic and the radiograph showed continued root development, a healthy apical periodontium, and, importantly, no calcifications in the remaining pulp (as is often seen with a calcium hydroxide therapy). A radiograph taken of the contralateral tooth showed similar root development.

Case 3: Primary endodontic treatment of a nonvital pulp

This is a case of a mandibular first molar with signs and symptoms of a periapical lesion (Fig. 10). The tooth was treated over two visits with an intracanal medication (calcium hydroxide). Three weeks later, the obturation was carried out with BC Sealer and gutta-percha using a singlepoint technique. The one-year follow-up radiograph showed signs of periapical healing.

Case 4: Apicoectomy and retrofill

A patient presented with clinical symptoms and radiographic signs of post-endodontic disease (Fig. 11). It was determined that the crown and the post were well adapted and an apicoectomy was to be performed. After apicoectomy, the canal was instrumented with an ultrasonic tip to its length and until the tip of the post. The canal was filled with BC Sealer first and a 2 mm plug of BC RRM Putty was condensed inside the retrograde cavity. The one-year follow-up showed radiographic signs of advanced periapical healing.

Conclusion

Pre-mixed bioceramic materials are hydrophilic, do not shrink and are insoluble in tissue fluid. With both antimicrobial and sealing properties, pre-mixed bioceramics are unique materials available in endodontics that have changed the way we perform both vital pulp therapy and root canal therapy. For root canal therapy, they contribute to the success of both the microbial control phase (instrumentation, irrigation and intracanal medication) and the filling phase (root and top filling) of root canal therapy. This allows the practitioner to perform the microbial control without removing dentine unnecessarily, leaving a stronger root for restorative reconstruction. Premixed bioceramics are also an essential element in the indirect and direct pulp capping and pulpotomy procedures owing to their sealing ability and the fact that they do not discolour the surrounding dentine. Because of these properties, more vital healthy pulps can be maintained, ensuring a healthy surrounding periodontium. For these reasons, pre-mixed bioceramic materials are now the material of choice for pulp capping, pulpotomy, perforation repair, root end filling, obturation of immature teeth with open apices and sealing of root canal fillings of mature teeth with closed apices.

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about

Dr Gilberto Debelian received his DMD from the University of Sao Paulo, Brazil, in 1987. He completed his specialisation in endodontics at the University of Pennsylvania School of Dental Medicine, Philadelphia, US., in 1991, where he received the Louis I. Grossman postdoctoral student award in endodontics. He completed his PhD studies at the University of Oslo, Norway, in 1997, for which he earned two scientific awards, from the European Society of Endodontology and the Norwegian Dental Association, respectively, also in 1997. He is an adjunct visiting professor in the postgraduate programme in endodontics at the University of Pennsylvania. Dr Debelian maintains a private practice limited to endodontics and has an advanced endodontic microscopy center (ENDO INN) in Norway. He has authored six chapters in books on endodontics, one book on endodontics, and more than 80 scientific and clinical papers.

Dr Martin Trope received his BDS in Johannesburg, South Africa, in 1976. In 1980, he moved to Philadelphia to specialise in endodontics at the University of Pennsylvania. After graduating, he remained as a faculty member until 1989, when he became Chair of Endodontontology at Temple University, School of Dentistry. Philadelphia. In 1993, he accepted the J.B. Freedland Professorship at the Department of Endodontics at the University of North Carolina at Chapel Hill School of Dentistry, US. Dr Trope is now a clinical professor at the Department of Endodontics of the University of Pennsylvania School of Dental Medicine. He is also in private practice in Philadelphia. Dr Trope has served as a director of the American Board of Endodontics. His work has been published in numerous journals and book chapters. In 2002, he was awarded the Louis I. Grossman Award for cumulative publication of significant research by the American Association of Endodontists. Dr Trope has created Next Level Endodontics on his extensive academic background and real-world experience in private practice.
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The restoration of endodontically treated teeth (ETT) has been guided historically by anecdotal empiricism rather than biomechanical dynamics. Decisions regarding the configuration of the restoration, the diameter of the post channel, and the post and core materials to be used have plagued foundational dentistry for decades.1, 2 The loss of coronal tooth structure due to caries,3 excessive access cavity design4, 5 and the taper of the root canal preparation are vectors that will create stress at the cervical region during functional loading.6, 7 The ongoing confusion regarding design and materials has caused paradoxical statements and illogical contradictions to be factored into the restorative matrix for ETT.

The introduction of fibre posts has altered the root to restoration harmonic. Fibre posts provide a reliable alternative to metal posts (cast or prefabricated), as their modulus of elasticity (20 GPa) is closer to that of dentine than that of metal posts (200 GPa). Stiff, hard metal posts transfer forces along their long axis, creating a wedging effect on tooth structure. This can lead to catastrophic failure. The use of fibre posts obviates such an event.8, 9

Factors in the decision-making process for the use of posts include many components (Table 1).10–24 ETT are weakened by the loss of strategic tooth architecture, resulting in structural and occlusal compromise. This is dependent on the amount of native tooth structure removed owing to previous or existing caries, the state of the current restoration and the volume of tooth structure removed during the endodontic treatment procedure. ETT are more vulnerable to loss than teeth with vital pulps owing to the possibility of either recrudescent or persistent post-treatment disease subsequent to root canal therapy.25 Historically, ETT were considered to be brittle, subject to fracture owing to the loss of tooth vitality, decreased moisture content, resultant inelasticity and the loss of collagen cross-linking. Contemporary studies comparing ETT to contralateral vital teeth challenge these findings: no decrease in compressive or tensile strength was associated with changes in the water content of dentine.26–30

In the case of ETT, the distribution of stress concentration zones and the magnitude of tensile stresses have been perceived to increase significantly when tooth structure is lost or occlusal loads are delivered off-angled to the long axis of the tooth. Fracture resistance is a function of resistance to deformation under load. Restorative materials are less likely to endure stress vectors with sustained load, further validating the need for bio-minimalism of ETT restorations.31–35 Also, the loss of tooth structure at the floor of the pulp chamber in ETT leads to significant biomechanical changes in as little as three weeks and ensuing recontamination of the pulp canal space, resulting in a higher incidence of fractures.36, 37 The more native tooth structure retained in ETT, the more enhanced the load management during function, the more effective the
stress management and the more predictable the long-term prognosis.\textsuperscript{38, 39}

**Biologic width**

Biologic width is the natural seal that develops around teeth and protects the alveolar bone from infection and disease (Fig. 1). The dimension of biologic width is not a constant; it depends on the location of the tooth in the alveolus, and it varies from tooth to tooth and the configuration of the tooth. Biologic width is essential for the preservation of periodontal health. It is sustained by the removal of any irritation that might damage the periodontium (marginal discrepancies). Exposure of sufficient sound tooth structure in the case of a deep subgingival tooth fracture or carious lesions enhances the retention of the restoration, ensures accurate impression taking and enables correct placement of the restorative margins without violating the biologic width. This is an imperative in the aesthetic zone in patients with uneven gingival margins or excessive gingival display.\textsuperscript{40, 41}

The choice of marginal position is either supragingival, equi-gingival or subgingival. Restorations placed where the alveolar bone is thin or the gingiva is thin highly scalloped are prone to recession.\textsuperscript{42, 43} When a restoration invades the biologic width, the body's response is to move the attachment zone apically until a tolerable biologic width is re-established.\textsuperscript{44}

**Ferrule**

The ferrule effect is an enduring foundational tenet in restorative dentistry. It is defined as the height of natural tooth structure extending from the crown margin coronally. Numerous studies have reported that a 2 mm ferrule is required to resist displacement\textsuperscript{45, 46} of the crown from the remaining tooth structure. The effectiveness of the ferrule in the restoration of ETT is determined by (1) the height and width, (2) the number of remaining walls, (3) the location of the ferrule, (4) the condition of the residual tooth structure, (5) the tooth type and (6) the degree of parafunctional loading (Fig. 2).\textsuperscript{47}

Exposure of sufficient sound tooth structure in the case of deep subgingival fractures and/or carious lesions enhances the retention of the restoration and enables nally. Numerous studies have reported that a 2 mm ferrule is required to resist displacement\textsuperscript{45, 46} of the crown from the remaining tooth structure. The effectiveness of the ferrule in the restoration of ETT is determined by (1) the height and width, (2) the number of remaining walls, (3) the location of the ferrule, (4) the condition of the residual tooth structure, (5) the tooth type and (6) the degree of parafunctional loading (Fig. 2).\textsuperscript{47}

Exposure of sufficient sound tooth structure in the case of deep subgingival fractures and/or carious lesions enhances the retention of the restoration and enables
correct placement of the restorative margins without violating the biologic width. This improves aesthetics in patients with uneven gingival margins and excessive gingival display. In situations where a substantial volume of tooth structure is lost, adhesive materials will not overcome the lack of ferrule and should not be an alternative to sound engineering principles when restoring ETT.

There are two ferrules; the crown ferrule and the core ferrule. The greater the height of residual tooth structure above the margin of the preparation (crown ferrule), the greater the fracture resistance. The same premise applies to the buccal thickness (core ferrule). Ideally, a 2.0mm crown ferrule and 2.4mm dentine thickness (core ferrule) minimises the fracture potential in molars. Full-coverage preparation for ETT maxillary and mandibular molars, regardless of the coronal ferrule height, results in diminished buccal thickness and increased fracture potential (Fig. 3).

There are numerous contra-indications to achieving an ideal ferrule: immunological disease, close adjacent roots, tori, the ascending ramus, muscle insertions, furcation exposure and lip position. It is best to do a risk–benefit analysis by creating a provisional restoration prior to crown lengthening to ensure that the restorative treatment plan objectives can be met (Fig. 4).

The paradigm shifts

The developments in adhesive restorative technologies and techniques have enabled functional and aesthetic reconstruction of debilitated tooth structure when adequate coronal tooth structure remains. A more conservative,

---

**Figs. 6a & b:** Prior to the nickel-titanium era, the traditional endodontic cavity preparation for incisors included the coronal aspect of the cingulum. The coronal tooth structure was weakened by the removal of excessive lingual tooth structure (a). Conservative endodontic cavity preparation for incisors minimises tooth structure removal. The use of CBCT in endodontic therapy targets a direct trajectory to the root canal space (b). **Fig. 7:** Traditional endodontic cavity (TEC) preparation in molars diminishes the amount of peri-cervical dentine retained and heightens the risk of fracture. **Fig. 8:** Conservative endodontic cavity (CEC) preparation in molars increases the resistance to fracture by minimising the removal of coronal tooth structure. TEC = traditional endodontic cavity.
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non-invasive rehabilitation is possible for rebuilding the integrity of the residual tooth structure. Improvements in direct restorations relating to the enhanced properties of composite resins have engendered a shift in the traditional default full-coverage treatment plan. In order to compensate for parafunctional occlusal forces, the marginal placement of a protective restoration should provide cuspal coverage. Posterior ETT have been reported to have greater cuspal flexure than non-ETT. Teeth missing marginal ridges allow greater cuspal flexure than teeth with intact marginal ridges, whether endodontically treated or not. Direct or indirect onlays can be used when there is residual tooth structure that is not undermined and if the marginal ridges are intact. Onlays with cuspal shoeing and full-coverage crowns restrict cuspal displacement and will prevent coronal fracture under loading (Fig. 5).

Clark advocates a substantially altered perspective on the reconstruction of ETT: (1) enamel bevels; (2) flared walls; (3) aluminium oxide-blasted; (4) and etched and uncut enamel. He advocates monolithic composites, in contrast to porcelain fused to metal, dilithium silicates and zirconia. He recommends not layering, the use of a translucent matrix system and the removal of biofilms with a slurry of pressurised air, water and mild abrasive.

Access cavity design revision

Recently, a trend towards patient-centric conservative endodontic cavities (CEC) has changed the focus of restoration of ETT. As the adhesion era in restorative dentistry progresses, extra-coronal restorations requiring minimal preparation are replacing full-coverage restorations, depending upon the volume of tooth structure remaining. The conservative endodontic cavity preparation concept recognises that endodontics is restoratively driven; it is an access to apex, apex to access paradigm that preserves peri-cervical dentine to diminish the potential for fracture. Traditional endodontic cavity preparation is procedure-centric and prone to structural compromise. Logically, a balance between the preservation...
of native tooth structure and dentine removal for access to the canal system is beneficial. However, a minimal access could compromise the efficacy of debridement and disinfection, as it limits access to the entirety of the root canal system. The size reduction engenders the possibility that infected tissue could remain and iatrogenic symptoms ensue (Figs. 6a–8).60

Decision-making for restoring ETT:
- Remove the restoration(s) and carious tooth structure prior to endodontic treatment in order to evaluate the restorative matrix.
- Assess how occlusal forces affect the ETT regarding the angulation and biomechanics of the residual tooth structure. Determine the algorithm of success.

Fig. 12: Composite or ceramic overlays are necessary when parafunctional forces are significant. Figs. 13a & b: Composite or ceramic endodontic crowns may be used when parafunctional forces are light and greater than half of the tooth structure remains (a). Composite cores and full-coverage restorations are indicated when parafunctional forces are significant and greater than half of the tooth structure remains (b).
with canine-protected occlusion or group function on a single tooth, a bridge abutment, an abutment for a removable partial denture or a single tooth adjacent to an implant-retained prosthesis:

– Crown lengthening considerations:
  · short clinical crowns;
  · placement of subgingival restorative margins;
  · excessive occlusal or incisal wear;
  · inadequate interocclusal space;
  · partial restorative ferrule.
– Boxes or grooves for secondary retention
– Would cementation of a crown on tooth structure be more effective than on core material?
– Choice of bonding agent, total-etch or self-etch resin cements

Conservative, non-invasive rehabilitation in the adhesion era:
– Are posts a prerequisite for all ETT?
– Is there an evidence-based data analysis that has found that fibre post systems are preferable to cast or prefabricated metal post systems?
– Is there an evidence-based data analysis that has found that restorations without posts are reliable and predictable?
– Are there alternative means by which to reinforce teeth?
– Are there predictable adhesive restorative protocols for ETT?

Restorative algorithms are presented in Table 2 and Figures 9a–14b.48

Conclusion

The journey from anecdotal empiricism to scientifically validated protocols used for the restoration of ETT continues. Fundamental best practices are changing. Historically, posts/cores and the circumferential reduction of residual tooth structure were the standard technique for restoration of ETT. These aggressive procedures appeared to enhance failure possibilities. Investigations from the past and those ongoing do not provide evidentiary science that conclusively substantiates post composition, post shape, core material choice, or ferrule height and width. Improvements in dentinal adhesives and bio-smart materials appear to provide an alternative restorative paradigm with maximum preservation of tooth structure and a balance between aesthetics and structural resilience.

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

about

Dr Kenneth Serota graduated with a DDS from the University of Toronto Faculty of Dentistry in Canada in 1973 and received his Certificate in Endodontics and Master of Medical Sciences from the Harvard–Forsyth Dental Center in Boston in Massachusetts in the US. Active in online education since 1998, he is the founder of the ROOTS endodontic forum and the NEXUS interdisciplinary forum. Dr Serota is an adjunct clinical instructor in the University of Toronto postdoctoral endodontics department.
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Hi! I am Dr Anna Maria Yiannikos and I am very happy to share the 7th part of this loved series filled with communication protocols with you. This series includes the most popular and challenging scenarios that might occur in your dental practice and presents successful ways of how to deal with them—so your patients will always leave your practice feeling satisfied and thinking: “My dentist is THE BEST!”

Each article of this series will teach you a new, easy to use specialised protocol, which can easily be customised and adapted to your own dental clinic’s requirements and needs right from day one.

Let’s start with today’s challenging topic which is... how to offer VIP services to your distinguished patients. Imagine, that the atmosphere in your clinic is unique, ideal for VIP patients. You probably already know this, but these patients are less affected by the recession. Might this fact somehow relate to you? Of course, it does. These are the patients who will have a full-mouth reconstruction done without second thoughts. These patients are also the ones who will pay you without a hassle. Thus, your desire should be to attract this group of patients. Is there anything you can do in order to encourage them to choose you? Yes, there is!

5 revolutionary tips

I am going to share five revolutionary tips with you that guarantee this wonderful outcome. Are you ready to attract your VIP patients?

1. Have a special website section
Create a special VIP section on your website providing all information exclusively for their superior needs. Here you can describe in detail why your clinic is the one they should come to and why it absolutely has to be their first
choice. Offer them extra incentives like a limousine service and remember, they already expect such amenities.

2. Create a VIP environment
Adapt your clinic’s environment according to their wishes and expectations. You can, for example, have a private entrance only for them, since they hate others gossiping about them.

3. Offer first class amenities
Treat your VIP patients as if they were on a first-class flight. Offer them warm towels before and after the treatment, or a special dental kit (with toothbrush and toothpaste), that has your logo and their name on it. Thus, equipping them with the perfect accessory to use after a quick brunch. Keep in mind that this group of people sometimes does not even have the time to eat.

4. Pay full attention
Assign one of your staff members to be at the individual service of your VIP patients during their entire visit to your practice. Accompany them from the time they arrive at your clinic until the time they leave. They expect your and your staff’s full attention, without disturbance—at all times.

5. Avoid delays
For your VIP patients, time is money. Therefore, they hate waiting. So, offer them a quick and excellent experience.

Are you ready?
It really is this easy. Plus, you will gain the reputation of being a VIP dentist. Are you wondering, why that should be so vital? The reason is that people love to be associated with distinguished professionals. If you think about it, this is exactly the same situation as with upscale brands, like Gucci or Prada. People love buying such brands since their high status is easily recognised! And that is why your clinic will in the end be full of patients who love to be associated with your name! That would be just perfect, wouldn’t it?

This is very useful insight, don’t you think? I am sure that you are looking forward to the next issue of laser magazine, where I will present the eighth part of this unique series of communication concepts to you. Are you wondering what will be the next beautiful and interesting topic? We will take a look at how to transform a fearful patient into a loyal one. You will certainly agree with me, that this is a regular situation that we all face in our clinics and I will thus teach you 5 essential ways to tackle it.

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

contact
Dr Anna Maria Yiannikos
Adjunct Faculty Member of AALZ at RWTH Aachen
University Campus, Germany
DDS, LSD, MSc, MBA
dba@yiannikosdental.com
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Products and services that are linked to one another support dentists’ individual treatment styles with the Endo-System through all treatment steps. Thus, peace of mind is included for dentists and patients, from preparation of the root canal and thorough irrigation to complete obturation and post-endodontic care. The innovative products by VDW for the whole treatment process are the decisive factor for the success and high added value of the Endo-System.

“Every dentist wants safe and efficient endodontics that can be easily integrated into the processes of the dental practice,” says Christiane Silber, Key Account Manager for Institutional Clients at VDW. “VDW not only has almost 150 years of endo expertise but also consistently integrates the results from research and development and the close cooperation with science and practice into new concepts, innovative products and systems. With the Endo-System, we offer our customers a comprehensive range of solid products and services, allowing them to concentrate fully on the right therapy.”

Combination of tradition and continuous innovation
As a specialist in endodontics and an innovation driver with almost 150 years of experience in research and development, VDW has played a major role in the rapid development of endodontics and is now one of the best-known global brands in the field. The company history is a story of innovations that are proven and based on science and have resulted in validated long-term clinical success. In 2010, a new era began with the RECIPROC system for preparation of root canals using reciprocating motion with only one instrument. VDW has most recently cemented its claim as an innovator and leading endodontic brand with the introduction of the EDDY irrigation tip, the RECIPROC blue file system and R-PILOT, the first motor-driven glide path file for use in reciprocating motion.

Endo in the DNA
Its long-standing specialisation in endodontics has driven the company’s strong growth. This strength is the basis for the continuing development of concepts and products. With the Endo-System, VDW delivers an innovative, effective, profitable and high-quality solution that improves the quality of endodontic treatment even more and accompanies dentists into the future. “Endo Easy Efficient” is not only the slogan of VDW but also both a promise and a commitment.

www.vdw-dental.com
Modular nickel-titanium (NiTi) systems enable the endodontic expert to work flexibly for a variety of indications and to prepare most patient cases efficiently and reliably with a reduced file sequence. For strongly curved canals, the dentist can now use a special glide path file in addition to the classic file sequence.

Additional glide path file for strongly curved canals

The internationally leading dental specialist COLTENE has once again complemented its versatile HyFlex NiTi range with a further useful addition: a new HyFlex EDM glide path file is now available in the range for the preparation of strongly curved and very narrow canals. The HyFlex EDM GPF 15/.03 is a flexible glide path file that ensures optimum shaping of the access cavity. Even S-shaped canals can be prepared safely and competently with the additional instrument. Like usual, the dentist subsequently enlarges with the glide path file size 10/.05 and the HyFlex EDM preparation file 20/.05. The recommended sequence for very narrow canals thus remains clearly structured and easily manageable for the entire practice team. Depending on the initial situation and personal preferences, the 25/.12 orifice opener can be used beforehand as an option.

The good cutting performance and fracture resistance of the flexible NiTi files are due to a special manufacturing process referred to as “electrical discharge machining” (EDM). The robust high-performance instruments are designed for endodontic beginners and dentists who wish to produce reliable results quickly with a reduced number of files.

Expanded file sequence for maximum flexibility

The novel HyFlex EDM GPF 15/.03 fits harmo-

niously into the existing portfolio of HyFlex files from COLTENE. One of the special features of the NiTi file series is the specially developed CM (controlled memory) treatment, thanks to which the files can be pre-bent similar to classic stain-

less-steel files and demonstrate almost no recov-

ery effect. This allows them to move optimally in the centre of the canal to prepare all canal walls evenly and thus significantly improve preparation efficiency. In addition, the risk of a false canal is minimised.

With the HyFlex EDM Shaping Set Max Curve, the complete sequence of special files for strongly curved canals will be available as a practical box from dental retailers from the second quarter of this year.

Incidentally, the COLTENE Group’s merger with French endodontic expert Micro-Mega in autumn last year will expand its portfolio of clever endodontic solutions, ranging from preparation to obturation, in the long term. More information on HyFlex EDM GPF and other products is available at www.coltene.com.
This year, VDW is celebrating its 150th birthday—one and a half centuries of expertise in developing innovative products for root canal therapy is an impressive achievement! With a passion for endodontics, VDW is dedicated to offering comprehensive endodontic care and improving tooth preservation globally. During IDS 2019, Dental Tribune International spoke with Sonja Corinna Ludwig, Director of Global Sales and General Manager of VDW, about the company’s anniversary celebration, newest products and development strategies.

VDW is celebrating its 150th anniversary. Happy birthday to you and your team! How does this major accomplishment feel?

Thank you! It feels very good, but most of all, it feels like a family birthday, not a company one. I have been with VDW since 2007 and feel like a member of a big family. It is because of the people, a bond we have, and a very special relationship with our customers, too. At VDW, we have a passion for what we do, and this passion fosters really strong bonds.

Our anniversary is much more than a birthday: it is a timeline of historical events. For 150 years now, we have been setting standards for modern endodontics with our dedication to quality, precision and innovation. Since its founding in 1869, VDW has grown into one of the leading brands in this field.

During the first day of this year’s IDS, we had a wonderful press party at our booth. Many press representatives and employees were there. A special highlight was the presentation of our mobile training centre, where dentists can attend VDW seminars. It is arranged in the interior of an aeroplane, giving rise to our celebration motto: “Join our ride!”. This mobile training centre not only functions during
trade fairs and shows, but actually travels around the Benelux region, Germany and Northern countries; for example, it was in the Netherlands at the beginning of this year.

But our 150-year anniversary celebration is not only a commemoration of the history of the company’s long-term success, but also our way of saying “thank you!” to everybody who has been and is involved in our success. By this, I mean our employees and representatives all around the world, the key opinion leaders and scientific organisations we work with, and dental professionals, distributors — all our customers.

**Which are some of the main markets in which VDW wishes to pursue growth?**

VDW is a Munich-based company, but we are present in over 80 countries all over the world. Although Germany respectively the D-A-CH region was, is and will always be the most important market from a strategy point of view, our worldwide presence and growth are very important to us, too.

At the moment, Asia, more precisely China, is definitely one of the main markets in which VDW wishes to grow. Another important market is Latin America. We are very much dedicated to developing our presence in Latin American countries, and so far, we have been very successful there. Then, of course, there are the central European countries like Poland, Hungary, Romania and Bulgaria, which for us are fast-growing markets in Europe at the moment.

But we are, of course, active in all countries where our products are present, and we always try to create a very special connection, as VDW follows the business-to-business model, so we don’t sell our products directly to dentists but through our distributors.

**Two years ago, at IDS 2017, VDW announced two innovations for glide path creation and reciprocating motion: R-PILOT and RECIPROC direct. What are the new products VDW introduced this year?**

R-PILOT and RECIPROC direct have been very important and successful products. Everybody was waiting for completion of the CONNECT family, and so this year we added two more products: VDW.CONNECT Locate, a smart apex locator, and VDW.ROTATE, the new range of rotary NiTi files.

VDW.CONNECT Locate detects the file position during root canal therapy. It connects wirelessly (via Bluetooth) with the VDW.CONNECT application, allowing real-time visualisation of the file progression on an iPad, which can be shown to the patient, too. Locate is a small and user-friendly device which can be placed on the tray.

As for the rotary files, while RECIPROC blue is still our focus and the most important product in our portfolio, as an endodontic specialist, we wanted to respond to the fast-growing competition in this field and complement our range with a new rotary file. VDW.ROTATE offers a large variety of files—including a 3-file basic sequence for the majority of the cases—which allows clinicians to follow their own approach to treatment. It helps clinicians to easily deal with different canal anatomies.

We are very proud of both of these products, which perfectly embody the VDW spirit of innovation and passion for endodontics.

**Thank you very much for the interview.**
The International Dental Show (IDS) 2019, which ran over five days, from 12 to 16 March, in Cologne in Germany, more than fulfilled the high expectations of the international industry, again underlining its exceptional position as the undisputed leading global trade fair of the dental industry. The show was able to replicate the very good results of the previous event and the organisers realised their ambitious goals for greater internationality and higher quality in supply and demand. The outcome of the trade fair consequently led to satisfied exhibitors and trade visitors.

With 2,327 companies from 64 countries participating, IDS 2019 welcomed 20 more exhibitors, as well as over 160,000 trade visitors from 166 countries. The overall number of visitors rose by 3.2 per cent and the number of foreign trade visitors by 6.0 per cent. The exhibition space was expanded by over 4.0 per cent up to 170,000 m².

Mark Stephen Pace, Chairman of the Board of the Association of the German Dental Industry (VDDI), which is involved in organising the event, remarked: "The strengths of this leading trade fair can be expressed in the words ‘sporting, fair competition’: the comprehensive and internationally unique offering, as well as the exceptional performance and innovative strength of the industry, combined with the firm intention of all market players to improve continually and pursue success in direct competition. Anyone who wants to be successful in the dental industry faces performance comparison in Cologne. It is, thus, no surprise that the level of internationality of IDS has grown so substantially."

Gerald Böse, President and CEO of Koelnmesse, which stages the show, added: "IDS is a trade fair in a class of its own and always sets new benchmarks. It manages to surpass the already excellent results of the previous event every time." Both visitors and exhibitors are impressed by IDS: it is only here that one encounters supply and demand of such an extent, quality and level of internationality. "IDS is the undisputed leading global trade fair for the dental industry," he continued.

The official figures confirm the high level of internationality at IDS: 73.0 per cent of the exhibitors came from abroad (64 countries) and 62.0 per cent of the visitors from 166 countries, including Argentina, Australia, Brazil, Canada, Chile, Egypt, Japan, Korea, New Zealand, South Africa and the US, as well as many European countries. The number of countries of origin thus increased once again by 6.0 per cent. IDS 2019 recorded significant growth in the number of visitors from Asia (+23.1 per cent), Eastern Europe (+19.6 per cent), Africa (+17.0 per cent), Central and South America (+14.6 per cent) and North America (+5.3 per cent).

However, it was not only the level of internationality and number of visitors that particularly pleased IDS 2019 exhibitors; many also commented on the high quality of the visitors. An independent survey confirmed this: about 80.0 per cent of those who completed the survey were involved in procurement decisions, and 32.0 per cent of them decisively. The decision-making power among foreign visitors was even higher: over 49.0 per cent of the survey respondents stated that they were autonomously responsible for procurement decisions.
At the booths, it was reported that all of the occupational groups of the industry from all over the globe were present. According to the survey, the largest groups came from dental practices, dental laboratories and the dental industry, but schools and universities were also strongly represented. Almost 30.0 per cent of the respondents were either board members or company or plant managers.

Almost 80.0 per cent of the visitors who completed the survey were satisfied or very satisfied with the range of exhibition offerings. More than 93.0 per cent said that they would recommend a visit to IDS to a good business acquaintance, and 70.0 per cent of the respondents were already planning to visit the next IDS in 2021.

Dr Markus Heibach, Executive Director of the VDDI, was also pleased with the outcome of the trade fair: “The high level of satisfaction of our trade visitors and exhibitors is for us impressive confirmation of our efforts to make our guests’ stay as pleasant and successful as possible by offering them a cosmopolitan, hospitable and perfect service.”

**High interest in innovations**

IDS is the ideal business platform, especially for new companies on the dental market seeking to establish themselves with high-quality innovations. Steve Plakotaris, CEO and Managing Director of Australian start-up Dr Mark’s HyGenie, confirmed this: “As a world first oral hygiene innovation, with global brand potential, it made perfect sense to debut our company and removable oral appliance hygiene range at the world’s biggest and busiest dental industry showcase. Despite being a small Australian start-up, we felt right at home at IDS and the results have exceeded all our expectations. Contacts, connections and new friends are being made every hour of every day. We look forward to booking our place at IDS 2021.”

Both trade representatives and users were extremely interested in the state-of-the-art products and technologies on display. The focus of IDS 2019 was on products and systems for improved digital workflows and additive manufacture, new prophylactic formulas and filling materials, innovative intraoral scanners and implant designs, as well as flexible workflows for management of the laboratory.

**German dentist and dental technician associations strike a positive balance**

“IDS is a phenomenon: the atmosphere is so international, thirsty for knowledge and open that it was simply very inspiring once again this year. Digitalisation can improve the workflows of practices, but shouldn’t be implemented non-critically or too hastily,” said Dr Peter Engel, President of the German Federal Dental Association (Bundeszahnärztekammer), which is an IDS partner.

He underlined the significance of the dental industry as a major employer and economic driver in the health sector.
“A local dentist employs between four and five employees on average. Trained dental employees are the heart of every dental practice—without them a practice wouldn’t work. Skilled dental employees, therefore, require recognition, as well as inspiration and know-how,” he explained.

The same applies to dental technicians. Dominik Kruchen, President of the association of German dental technician guilds (Verband Deutscher Zahntechniker-Innungen), also an IDS partner, summed up as follows: “IDS demonstrated at what speed the digital dental world is developing. One has to weigh up the risks, recognise one’s own opportunities and take investment decisions based on good judgement.” On the role of dental laboratories, Kruchen commented that master dental technicians and their teams are irreplaceable experts in the provision of dental restorations. In close collaboration with dentists, their expertise, for example regarding the selection and use of different materials, ensures an individual offering for patients. “Well-trained young professionals are important for a strong dental technology trade. Highly trained young dental technician apprentices once again impressively demonstrated their skills at this year’s IDS in the scope of the Gysi prize competition,” he emphasised.

Social commitment of dentists

Following tradition, the German Federal Dental Association’s conference of aid organisations took place at IDS. It is a source of ideas for dental aid projects and offers a forum for personal exchange. Around 60 dental aid projects and organisations are currently represented within the association’s network, the essential aim of which is to provide mutual assistance and exchange. The projects provide aid and support in a number of ways within Germany and Europe, as well as worldwide. In Germany, for example, many dentists are very committed to helping people of lower socioeconomic standing and those in need of emergency assistance. These dentists treat people without health insurance and offer aid organisations both monetary and in-kind support. Many dental aid organisations are engaged in international projects that provide assistance in acute humanitarian situations such as natural disasters and in crisis regions or offer patients dental treatment locally.

IDS 2019 compared with IDS 2017 in figures

Hosted over a gross exhibition area of 170,000 m² (2017: 163,000 m²), 2,327 companies from 64 countries participated in IDS 2019 (2017: 2,305 companies from 60 countries). These included 628 exhibitors from Germany, of which 18 were new IDS participants (2017: 644 exhibitors, including 20 new companies), as well as 1,699 exhibitors from abroad, of which 49 were new IDS participants (2017: 1,661 exhibitors, including 44 new companies). The share of foreign exhibitors was 73 per cent (2017: 72 per cent). Including estimates for the last day of the fair, over 160,000 trade visitors from 166 countries attended IDS (2017: 155,000 trade visitors from 156 countries), approximately 62 per cent of whom (2017: 60 per cent) came from abroad.*

The 39th IDS is scheduled to take place from 9 to 13 March 2021.

Photographs courtesy of Koelnmesse (www.ids-cologne.de).

* The figures relating to visitors, exhibitors and exhibition space for this trade fair were determined and certified according to the standardised definitions used by the Society of Voluntary Control of Fair and Exhibition Statistics.
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www.icoi.org

**The ADA FDI World Dental Congress**
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San Francisco, USA
www.world-dental-congress.org

**19th Biennial ESE Congress**
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www.e-s-e.eu

**AAOMS Annual Meeting**
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www.aaoms.org

**CEDE—Central European Dental Exhibition**
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www.cede.pl

**16th ESCD Annual Meeting**
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Magda Wojtkiewicz (Managing Editor)
m.wojtkiewicz@dental-tribune.com
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Holbeinstr. 29 | 04229 Leipzig | Germany
Tel.: +49 341 48 474 302
Fax: +49 341 48 474 173
www.dental-tribune.com
info@dental-tribune.com
Imprint

Publisher/Chief Executive Officer
Torsten R. Oemus
t.oemus@dental-tribune.com

Managing Editor
Magda Wojtkiewicz
m.wojtkiewicz@dental-tribune.com

Designer
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Copy Editors
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International Headquarters
Dental Tribune International
Hobeinistr. 29, 04229 Leipzig, Germany
Tel.: +49 341 48474-302
Fax: +49 341 48474-173
info@dental-tribune.com
www.dental-tribune.com

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