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CASE SERIES/**CASI CLINICI**

# Treatment of obliterated root canals using various guided endodontic techniques

*Trattamento di canali obliterati con tecnica di endodonzia guidata*

**KEYWORDS**
*Endodontic access, Guided endodontics, Minimally-invasive, Calcified canal, CBCT, Intraoral scanning*

**PAROLE CHIAVE**
*Cavità di accesso, Endodonzia guidata, Minima-invasività, Canali calcificati, CBCT, impronta digitale*

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Received 2020, February 13
Accepted 2020, March 3

## Abstract

***Objective:*** *This article reports on four endodontic treatments of obliterated teeth using a static guided endodontic (GE) technique. The aim is to demonstrate the benefits and limits of static guided endodontics.*
***Cases:*** *The four patients were referred for endodontic treatment of an obliterated tooth. The teeth did not respond to pulp vitality test. Periapical X-rays and cone-beam computed tomography (CBCT) revealed the presence of a periapical lesion and root canal obliteration. Patients' consent was obtained to perform GE orthograde treatment. The clinical cases were treated by GE using different static fixed guides depending on the case: a closed guide and a metal sleeve and a open guide with a system guiding the head of the contra-angle.*
*Treatment planning and guide manufacture were achieved by means of software programs initially designed for implantology, but which can also be used by endodontists. Root canal patency was obtained in all patients. In each of the four cases, drilling was done using a small diameter (0.75 mm) cylindrical drill (FFDM Pneumat Tivoly; Bourges; France). Once canal patency was obtained using a manual file, classic endodontic treatment could be performed.*
***Conclusions:*** *Static GE assists endodontists in the management of complex cases by enabling centered drilling of the canal with minimum risk of deviating from the virtually planned path. The novel choice of a small-diameter drill (0.75 mm) helps maximize the preservation of the dental tissues.*

***Obiettivo:*** *questo articolo riporta quattro trattamenti endodontici di denti obliterati con una tecnica di endodonzia guidata (EG) statica. L'obiettivo è di mettere in evidenza l'interesse e i limiti dell'endodonzia guidata statica.*
***Casi:*** *i quattro pazienti si sono presentati in appuntamento per il trattamento endodontico di un dente obliterato. I denti non rispondevano ai test di vitalità. Le radiografie periapicali e la CBCT mostrano la presenza di una lesione periapicale e di un'obliterazione canalare. Con l'accordo dei pazienti, é stato deciso di realizzare un trattamento endodontico ortogrado con EG. Questi casi sono stati trattati con EG con diversi tipi di dime statiche: una dima "chiusa" e una boccola metallica, una dima "chiusa" senza boccola metallica, una dima "aperta", utilizzando un sistema che guida la testa del contrangolo.*
*Le pianificazioni e la creazione delle dime sono state realizzate con dei programmi inizialmente dedicati all'implantologia ma che sono trasferibili all'endodonzia. La pervietà canalare é stata ritrovata in ciascuno dei casi. In ognuno dei casi l'apertura é stata realizzata con una fresa cilindrica di piccolo diametro (0.75 mm) (FFDM Pneumat Tivoly; Bourges; France). Una volta ritrovata la percorribilità del canale con una lima manuale, il trattamento endodontico é stato eseguito in maniera classica.*
***Conclusione:*** *l'EG aiuta l'endodontista nella gestione dei casi complessi. Permette una apertura centrata sul canale con minimo rischio di deviazione significativa della traiettoria rispetto al progetto virtuale. La scelta di una fresa di piccolo diametro (0.75 mm) é innovativa in termini di conservazione dei tessuti dentali.*

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Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2020.34.01.06

## Introduction

The process of canal obliteration (CO) is characterized by the apposition of secondary or tertiary dentin, resulting in loss of volume in the pulpal space.
CO can result from various causes (1):
- Pathological: trauma, decays, iatrogenic factors (bulky restorations or orthodontic movements) or occlusal overload.
- Physiological: age-related.

According to the study by Holcomb and Gregory, 4% of the population is affected by CO (2). In the event of trauma, the incidence reaches 22% (3). Root canal obliteration is considered to be a defence mechanism of the pulp, the vitality of which is often preserved. Esthetically, this usually leads to yellowish discolouration, which can be treated by external whitening and/or by placing a veneer (4). Endodontic treatment is only indicated when the canal obliteration is associated with radiological signs revealing a periapical lesion or clinical signs of irreversible pulpitis. This clinical situation poses a challenge for the practitioner. Even using a microscope, the risk of intra-operative error is very high (5).
Traditional cavity access has a design that has been the standard for a long time (6). Recently, Clark and Khademi introduced a novel access cavity model which highlights preservation of dental structures (7, 8). A new approach to access cavity preparation was described for the first time in 2013 by Kfir et al. for the treatment of a type 3 dens invaginatus using an endodontic guide (9). For this purpose, they segmented the dental structure by means of CBCT to achieve a resin 3D model of the tooth. The model served to plan and manufacture a resin guide. As a result, a drill could be guided towards the invagination to be treated while preserving pulpal vitality of the tooth. Byun et al. (10) reproduced this technique to treat two teeth with complex endodontic anatomies. Shortly afterwards, Van der Meer et al. (11) suggested a digital planning protocol for endodontic use inspired by implantology protocols. They merged a DICOM file obtained by CBCT with a Standard Tessellation Language (STL) file obtained from an intraoral optical impression. They calculated the drilling axis with the aid of an implant planning software and created a virtual guide. The virtual guide was then downloaded as an STL file to print a resin guide by means of a 3D printer. The guide enabled the drill to be centred towards the canal of an obliterated tooth. Such planning of the access cavity made it possible to preserve the dental structure and avoid deviations that may jeopardize tooth prognosis (12).
Static Guided Endodontics (GE) was then made simpler by using a single software program combining all the stages of the planning process, from visualization of the STL and DICOM files, to design the static guide and then printing the guide in resin materials. Some authors have applied this technique in cases involving maxillary (13) and mandibular incisor (14) and molar (15) root canal obliteration, as well as for removal of fiber-reinforced posts (16). In this article, four clinical cases were described involving the use of an endodontic static guide to perform endodontic treatment in a calcified root canal.

## Report

*Case 1*
A 50-year-old female patient was referred following unsuccessful endodontic treatment on the mandibular right canine (tooth 43). She reported a trauma which had occurred 15 years before. The tooth presented with yellowish discoloration, was painful to percussion and reported a negative response to electric and thermal sensitivity tests (figure 1). This finding was confirmed by CBCT (VGI, Evo NewTom) with a 55 mm scan field of view and 100-micron resolution. The patient's informed consent was obtained to perform orthograde treatment by GE. The STL file of the arch

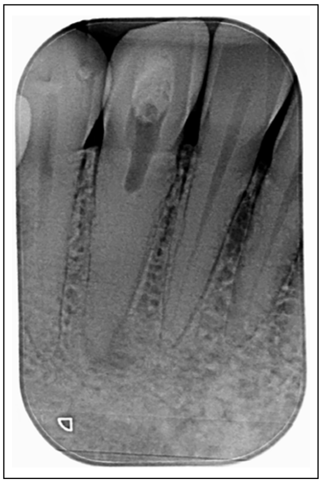


**Figure 1**
Preoperative X-ray. The patient was referred for treatment of tooth 43 displaying calcification and symptomatic periapical periodontitis.

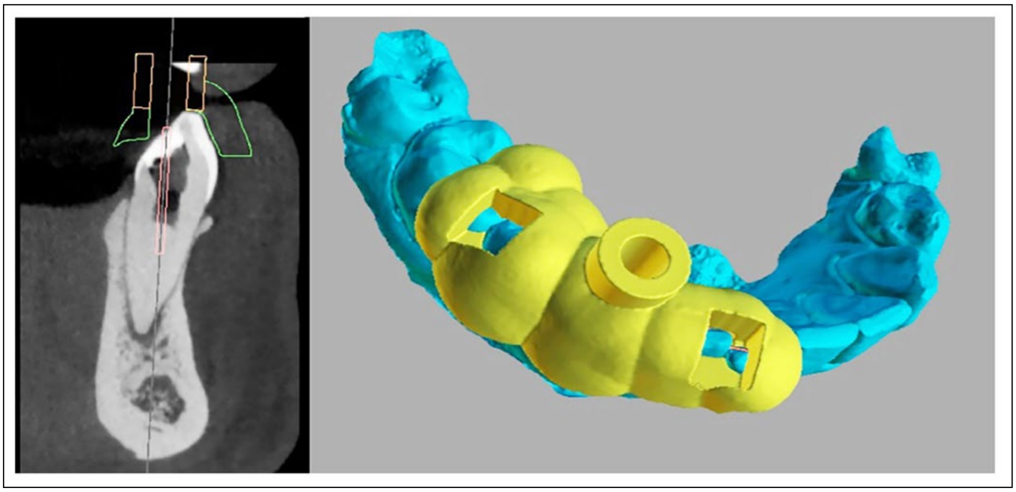


**Figure 2**
Planning the guide. The guide was designed using BlueSkyPlan freeware. The bur was designed and planned on the dicom file and oriented to ensure correct endodontic access to the calcified canal.

was obtained by optical impression and uploaded to the BlueSky Plan software (BlueSkyBio; LLC; Grayslake; IL; USA) The aim was to superimpose the digital image of the arch on the CBCT views. Merging of the two files was achieved by means of fixed reference points on the crown surface of all the teeth of the full arch. In this way, the inner surface of the guide can be modelled depending on the digital impression (figure 2). The sleeve slot was realised according to the position of the drill simulated on the DICOM images. Finally, two occlusal windows were virtually created on the guide to check proper clinical fit. The STL file for the guide was then downloaded and dispatched for 3D printing. The guide was printed in resin using a Formlabs 2 printer (Formlabs Inc; Sommerville; MA; USA). In fact, the metal sleeve was then inserted under friction into the resin guide to orient a drill 0.75 mm in diameter and 23 mm in length (FFDM Pneumat Tivoly; Bourges; France) (figure 3). During the clinical appointment the operative field was isolated using a rubber dam placed on several teeth to avoid interference between the guide and the clamp. The guide was tested to ensure a proper fit and stability on the teeth. The drill, mounted on a low-speed contra-angle, was inserted into the sleeve, then rotated at 20,000 RPM. The guide was kept very stable by the clinician during drilling. At every millimeter of progress along the canal, the guide was withdrawn to allow the access cavity to

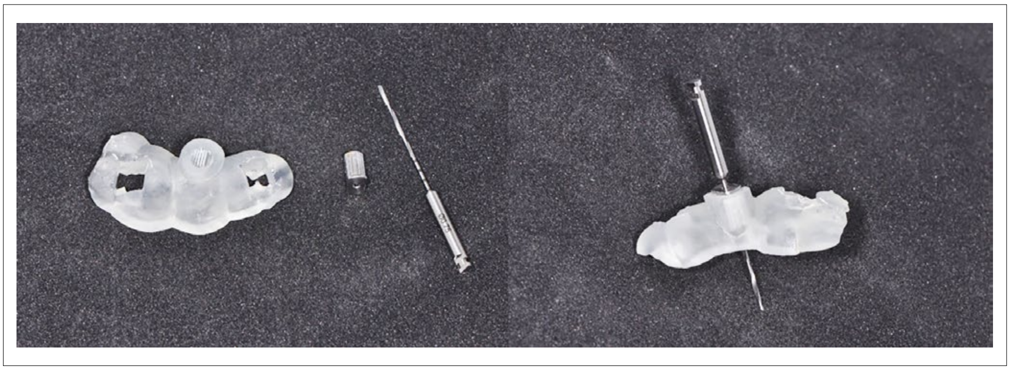


**Figure 3**
3D impression of the guide. The resin guide was printed; the bur used was cylindrical (0.75 mm in diameter and 23 mm in length) (FFDM Pneumat Tivoly) *(made by Asselin Bonichon lab)*.

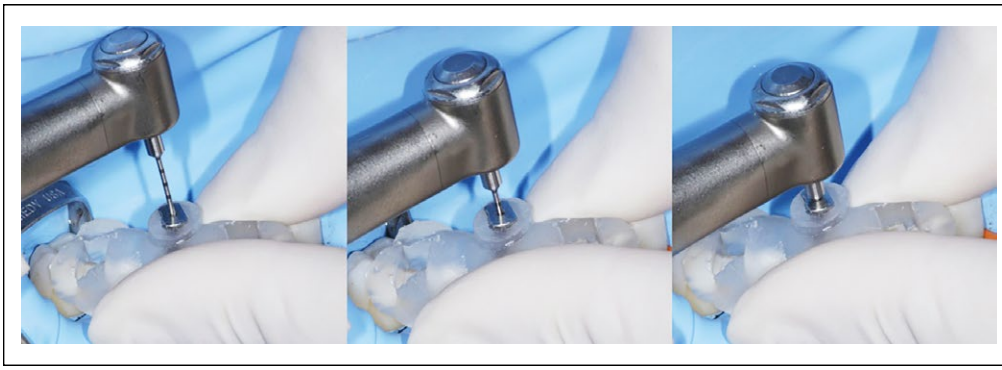
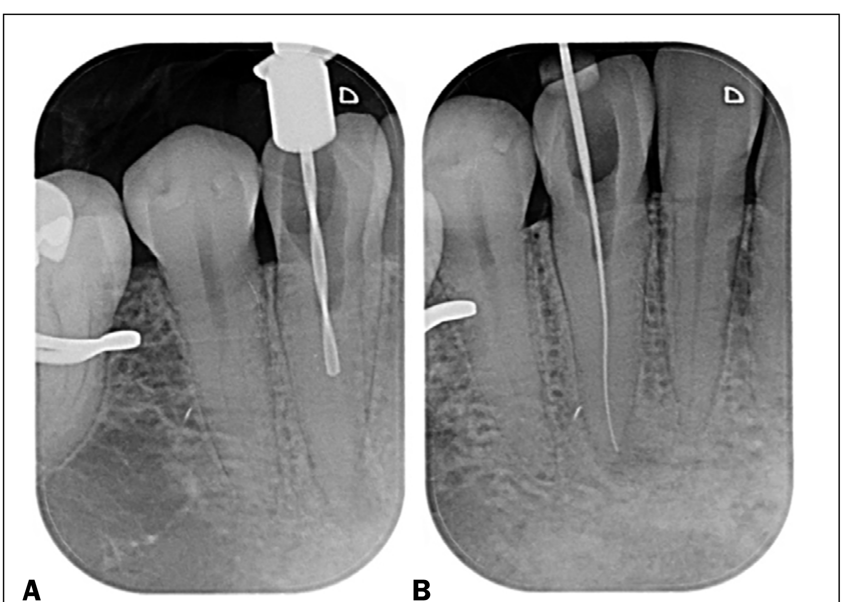


**Figure 4**
Drilling path. A staggered drilling pattern was performed. At every millimeter of progress along the canal, the guide was withdrawn to allow irrigation of the access cavity and avoid overheating of the dentin and accumulation of dentin debris.

be irrigated. The irrigation avoids overheating of the dentine and accumulation of dentine debris (figure 4). An intraoperative radiograph was taken to confirm the correct trajectory during the treatment (figure 5A). Once the drill was fully inserted into the sleeve, patency was checked by means of a C+ .06 file (Dentsply Sirona Endodontics, Ballaigues, Switzerland) and endodontic treatment was normally completed (figure 5B). Shaping was performed using the ProTaper Gold System (Dentsply Sirona Endodontics, Ballaigues, Switzerland). The irrigation consisted of a sodium hypochlorite 3% solution (Vistadental, Racine, Wisconsin, USA) and EDTA 17% solution (Vistadental, Racine, Wisconsin, USA) The canal was then filled using a warm vertical compaction technique (figure 6). Lastly, the tooth was obturated at crown level using an occlusal composite.

**Figure 5**
Intraoperative X-rays to confirm the axes **(A)** and restore patency **(B)**.




*Case 2*
A 46-year-old male patient was referred for esthetic reasons regarding the upper right central incisor (tooth 11). The tooth showed no response to electric and thermal vitality tests and was asymptomatic when subjected to percussion and palpation. The patient reported a trauma falling from his bicycle 15 years before. An emergency treatment was initially performed by his first dentist at the time of the trauma, but unsuccessfully. The tooth had been restored with composite. No symptoms had appeared over the years. Radiological examination by periapical x-ray and CBCT revealed a periapical lesion and the almost complete obliteration of the root canal of tooth 11 (figure 7A, C). GE treatment was scheduled in agreement with the patient. The treatment was performed using the same protocol as for case #1 (figure 8). The resin guide and the metal sleeve helped to obtain root canal patency 3 mm from the apex, following a 17 mm of coronal drilling through the guide. Once root canal patency was obtained, shaping was performed using the ProTaper Gold system (Dentsply Sirona Endodontics) and filling of the root canal was performed using a cold obturation technique combining Totalfill bioceramic sealer (FKJ, La ChauxdeFonds, Switzerland) and a single gutta-percha cone (PD, Vevey, Switzerland). The tooth was

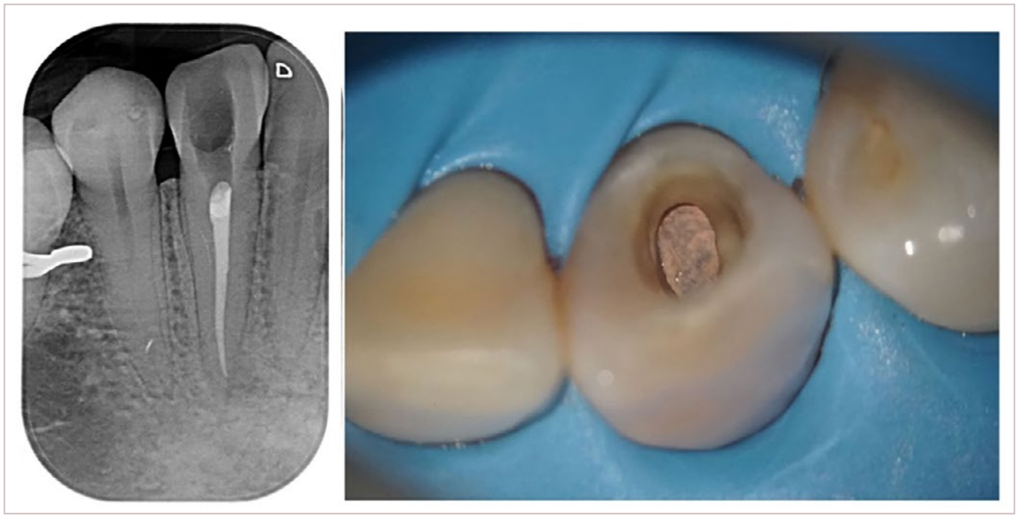


**Figure 6**
The endodontic treatment was performed using classical endodontic techniques.

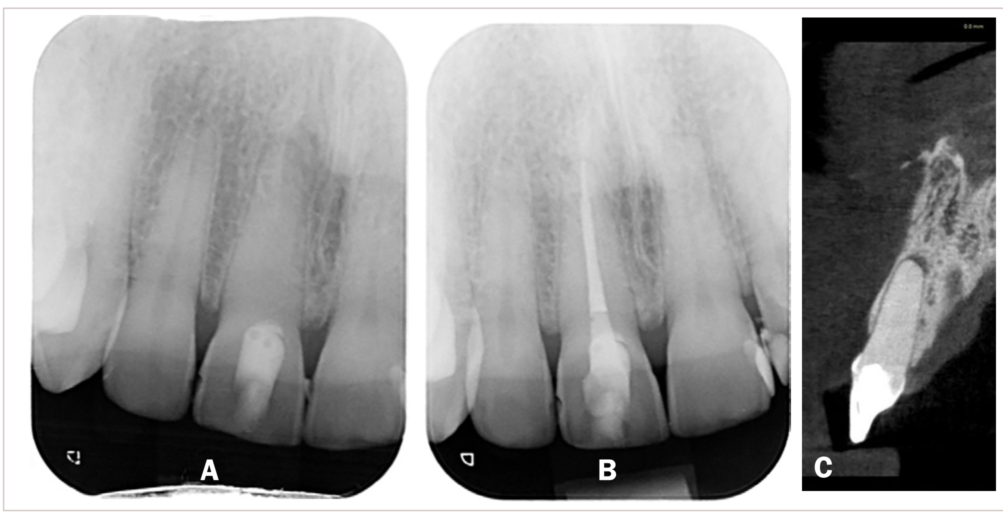



**Figure 7**
**(A)** Pre- and **(B)** post-operative X-ray and CBCT slice **(C)** of tooth 11 of case 2. Tooth 11 was calcified.

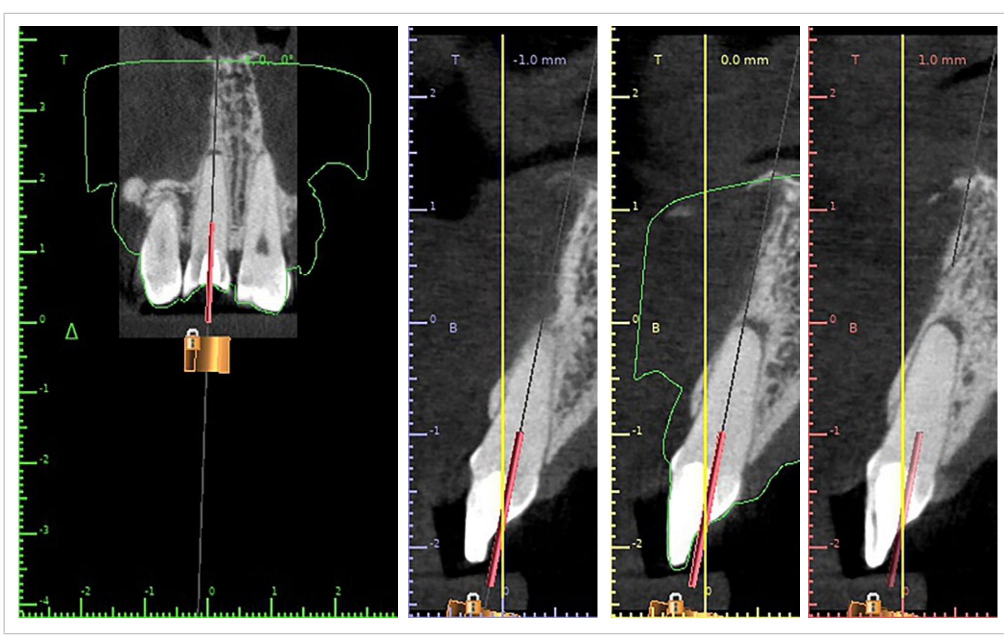



**Figure 8**
Planning endodontic access with BlueSkyPlan.

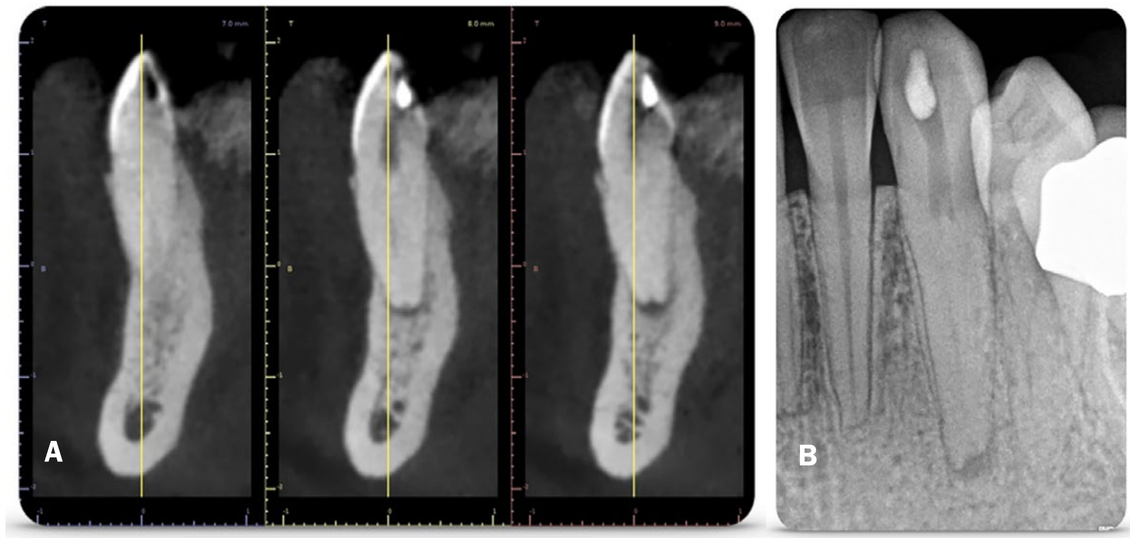



**Figure 9**
Pre-operative cbct **(A)** and X-ray **(B)** of tooth 33 of case 3. The patient was referred for treatment of tooth 33 displaying calcification and symptomatic periapical periodontitis *(courtesy Dr Virginie Touboul)*.

restored with glass ionomer cement (Fuji II, GC Corporation, Tokyo, Japan) and a resin composite resin.

*Case 3*
This 43-year-old female patient was referred by her dentist for orthodontic treatment on the mandibular left canine (tooth 33). She had a trauma on the left side of her mandible 8 years previously. The tooth became yellow in the recent years and symptomatic over the past few months. The patient complained of pain on percussion and described an episode of spontaneous pain which receded after antibiotic treatment. Following this episode of pain, her dentist attempted a first endodontic treatment, but unsuccessfully. The intra-oral radiograph showed a periapical lesion and root canal obliteration, confirmed by CBCT (figure 9A, B). The diagnosis was symptomatic apical periodontitis.
With the patient consent, GE treatment was planned. In this case it was decided not to place a sleeve. The static resin guide was fabricated with a guide hole 7 mm in length adapted to the drill diameter (figure 10)
The initial access achieved by the previous intervention was incorrect. Consequently, in order to make the access cavity along the axis of the root canal that was previously identified by the CBCT, it was essential to mark a reference point on the enamel through the guidance hole using a graphite pencil

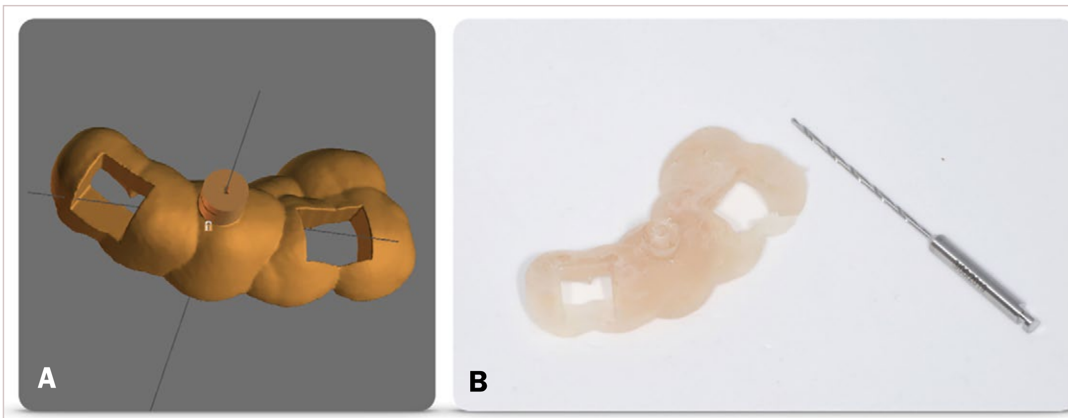



**Figure 10**
Planning **(A)** and Printing **(B)** the guide. The resin guide is sleeveless and was fabricated with a 7 mm in length guidance orifice and adapted to the drill diameter.

**Figure 11**
Marking a reference point for the first access. It is essential to mark a reference point on the enamel through the guidance hole using a graphite pencil lead.

**Figure 12**
Drilling path. Drilling was then performed following the protocol step-by-step used in Case 1.

lead (figure 11). A diamond bur was used to open the access cavity into enamel and to achieve a flat dentine surface perpendicular to the drill axis. Drilling was then performed following the protocol step-by-step used in Case #1 (figure 12).
Once the apical root canal patency was obtained using a manual file, shaping was performed using ProTaper Gold (Dentsply Sirona Endodontics, Ballaigues, Switzerland) and filling was carried out using a warm vertical compaction technique. The tooth was then restored with resin composite.

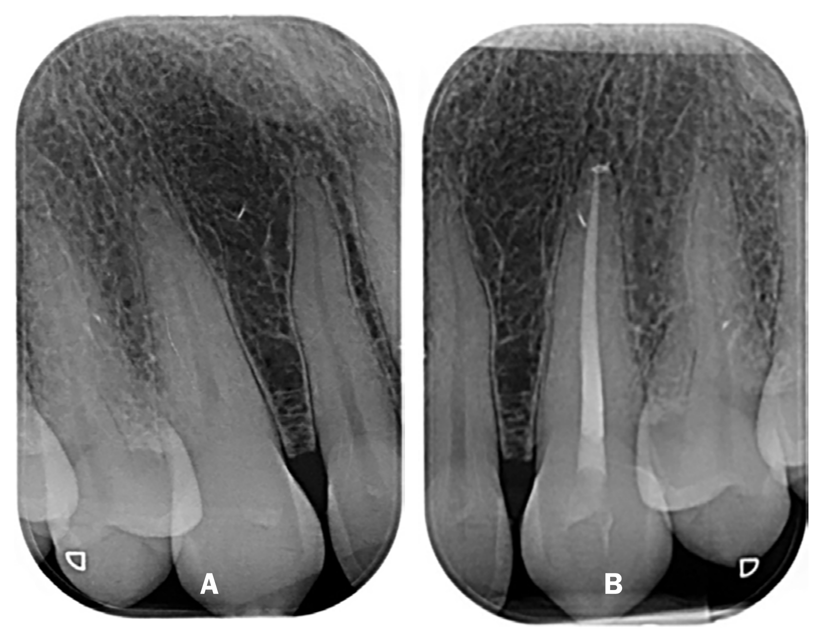



**Figure 13**
Pre- and postoperative X-ray case 4. This system enabled us to quickly locate the endodontic canal without excessive damage. Classic end of treatment was achieved *(courtesy Dr Cyril Perez).*

*Case 4*
A 35-year-old female patient was referred complaining of pain involving the maxillary right canine (tooth 13) over the previous 6 months. Clinical examination showed that the tooth was sensitive to axial percussion and buccal palpation. Electric and thermal sensitivity tests were negative. The tooth also displayed yellow discolouration. The patient could not remember having undergone a trauma in the past. Pulpal necrosis was diagnosed and canal obliteration was observed on radiograph (figure 13A). The CBCT provided by the patient confirmed the presence of canal obliteration up to the middle third. With the patient consent, orthograde endodontic treatment was planned using the 2ingis guided endodontics system. 2Ingis is a system of surgical guides originally designed for the placement of dental implants. The drilling guidance is obtained by a linear movement of the head of the contra-angle sliding through two rails incorporated in the drilling template printed. A silicon impression was taken during the initial visit. The impression was then scanned by the dental laboratory, which produced a STL

**Figure 14**
Planning the guide with SMOP software (2ingis).

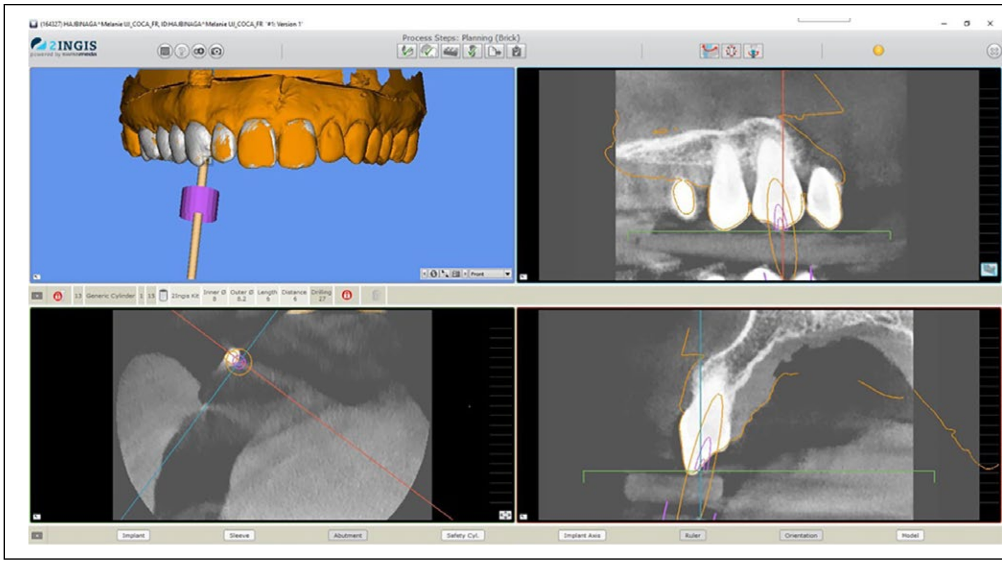


**Figure 14A**
The digital design of the 2ingis guide and his 3D impression. The guide is digitally designed using certain teeth for support.

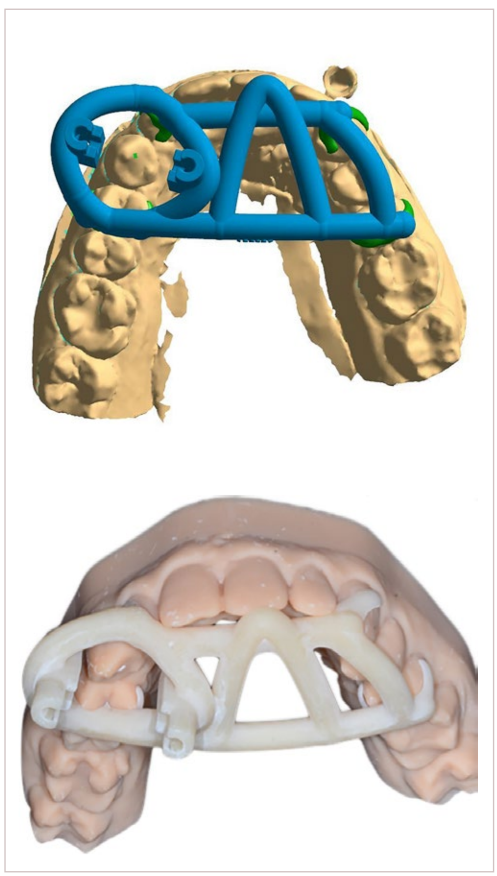


**Figure 15**
Clinical view. The 2ingis guide designed to direct the head of the contra-angle.

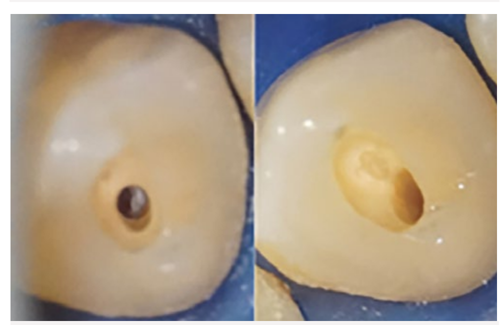


**Figure 16**
Cavity access with 2ingis technique: a diamond bur mounted on the contra-angle and guided by the 2ingis system was used to prepare the cavity access.

file of the model. The drilling plan was drawn up by the 2ingis company using SMOP software (Swissmeda; Baar; Switzerland) (figure 14). The plan was verified and validated by the operator and an endodontic guide was digitally designed using four teeth as support (figure 15) and printed. A diamond bur mounted on the contra-angle at a speed of 40,000 RPM and guided by the 2ingis system was used to prepare the access cavity into the enamel. Then, a 0.75 drill with

a guided low-speed contra-angle head at a speed of 20,000 RPM was used to penetrate into the dentine.
The irrigation is achieved by the water spray of the contrangle. This system enables to quickly locate the endodontic canal without excessive sacrifice of the tooth structure. A standard endodontic treatment was then performed in one visit once the canal orifice was located followed by the placement of a coronal resin composite restoration (figure 16).

## Discussion

In 2005, the American Association of Endodontists published a form for the assessment of endodontic treatment difficulty. Management of root-canal obliteration is included in the high level of difficulty (17). Different techniques have been reported for the management of obliterated canals. Some authors suggested orientating the axis of the access cavity along the axis of the tooth in order to improve visibility of the dentine (18). The use of dental microscope in conjunction with long-necked burs or ultrasound inserts was also recommended (18) It has also been suggested to take numerous intraoperative X-rays to control and reorientate the drilling axis to gain access to the canal (8). The new concept of guided endodontic access (GE) is based on the use of protocols from guided implantology to perform a safe cavity access in difficult cases as calcified canals. This technique consists of planning the drilling path using a software merging the STL and DICOM data. The digital guide exported by the digital project is printed with a 3D printer in a resin material.
The four clinical cases presented in this article demonstrated that conservative maintainance of sound dental tissues is one of the main advantages of GE. Less invasive than the classic techniques, GE also limits the risk of deviation and reduces operative time (19, 20, 21). Endodontic surgery also offers an alternative solution although, with this technique, the endodontic canal cannot always be cleaned along its entire length (22).
On the other hand, in situations involving obliterated canals after the curve, endodontic surgery is the most appropriate treatment approach. Studies on obliterated teeth are still needed to compare the respective success rates of endodontic surgery and GE orthograde treatment. Meanwhile, the two techniques remain complementary. Guided implantology supplies the know-how to enable its application to endodontics. It has been demonstrated that the guided technique can position an implant more accurately compared with a free-hand technique (23). As a result, the guided approach can be considered more predictable. Nonetheless, deviations ranging from 2.29° to 5.2° are considered tolerable in implantology (24, 25). In GE, such deviations can be considered significant in cases of very apical canal obliteration. Recently, several studies have attempted to validate this endodontic treatment technique for obliterated pulp canals. Buchgreitz et al. reported a linear drill deviation of 0.46 mm at the apical target (21). Two other studies have shown the presence of angle deviations ranging from 1.59° to 1.81° using drills with a diameter of 0.85 mm and 1.5 mm, respectively (19, 20). The authors judged these margins of error to be minimal.
The clinical protocol proposed in the present report include 3 main features:

1. The use of a static guide over only 3-4 teeth. Generally, the static guides presented in case reports involved the entire arch and are even stabilized in some cases with miniscrews inserted in the bone (26). A less extensive guide makes easier the isolation and the periapical radiography. Conversely, stability is diminished, although this had no great impact on the successful outcome of the presented clinical cases.
2. The use of a small-diameter drill (0.75 mm) (FFDM-PneumatTivoly; Bourges; France). The literature reports description of drill diameters between 0.85 mm and 1.5 mm (19, 20). A 0.75 mm drill permits a less invasive procedure, even to the apical third. On the downside, the smaller is the drill diameter, the more flexible is the drill and the greater is the risk of deviation during the

firsts steps of the access procedure. However, case 3 showed that even the apical region of the obliterated canal can be successfully reached. While the benefits of using less extensive guides and small diameter drills appear obvious, clinical studies are needed to confirm the reproducibility of the technique.
3. The planning and fabrication of the guide were done using the BlueSky Plan planning software program (BlueSkyBio; LLC; Grayslake; IL; USA). This software is free of charge and only the downloading of the STL file of the guide is subject to payment. A DICOM file taken from a CBCT and a STL file taken from a digital impression of the teeth may be merged in the system. CBCT scans can be performed in a radiology laboratory or in the dental office and digital impressions can be made in a laboratory from a silicon impression or directly in the mouth using an intra-oral scanner. The GE technique therefore may be also performed without any special equipment in the dental office.

The accuracy of GE drilling is linked to a series of errors to be avoided. Accuracy is dependent on the quality of both the CBCT and the digital impression, on the successful merging of the two files, on the drilling plan, on the printing of the guide and on the clinical step-by-step. During the planning stage, it may sometimes be difficult to locate the canal on the CBCT.

The literature reports that, in the event of pulpal canal calcification, the canal space of single-root teeth is always located in the center of the root in an axial view (18). Importantly, the drilling axis will sometimes be aligned with the main tooth axis, meaning the access cavity will be situated very close to the free edge of the tooth in the anterior region.

During the clinical procedures, the access cavity plays a crucial role. Its design must help avoid any interference between the drill and the cavity axial walls. The floor of the cavity must be flat and perpendicular to the drilling axis. Failing in this objective may lead to the fact that the drill could be deviated as soon as the drilling action begins and the tip may slide across the sloping cavity floor. The access cavity must be prepared using a diamond bur to start access in the enamel. To locate the access cavity, the guide can be used to mark the first point of contact through the sleeve by means of a graphite pencil. This phase can be repeated several times in order to find a flat central access point with no lateral interference. This step is essential whether preparing a first-line access cavity or during retreatment where the access already exists.

The second possible error during the clinical step-by-step may be connected to a precise positioning of the guide. Proper insertion of the guide must be verified using the openings on its occlusal surface. The guide must be held firmly in place during the drilling procedures to avoid it vibrating and being dislodged. Lastly, the contra-angle must be held as close as possible to the head of the instrument and should be brought down passively to avoid rotating the assemblage formed by the contra-angle, the drill and the guide.

Thus, a microscope can still provide a useful service. The endodontic guide serves to drill millimetre by millimetre towards the apex. At each step, the guide must be removed to allow the canal to be probed manually and to help check the canal patency. At all stages, when the guide is removed, the canal can also be rinsed out to prevent dentine remnants from accumulating and forming a blockage. Rinsing also avoids overheating of the dentine during drilling. Clinicians should keep in mind that CBCT resolution may identify a canal more apically that what may happen clinically.

Thus, it is important to try if a manual file may be inserted in the canal even if drilling is not arrived to the apical point of the guide, as the further the drill is used towards the apex, the greater is the

risk of deviating from the canal path. In the event of deviation, CBCT can be used to relocate the canal intra-operatively with techniques not using an endodontic guide.
Further advances in GE will possibly lead to the metal sleeve being not used, thus avoiding positioning errors when inserting the sleeve in the guide. In fact, depending on the printer and its settings, as well as the resin used to build up the guide, the sleeve can be inserted in the guide with varying degrees of passivity. It may happen that the sleeve moves in the guide or that it could not be completely inserted. Note that, when not using a metal sleeve, it is important to use guides made from very hard materials.
Unlike the previous cases that used closed static endodontic guides, in the case 4 the 2ingis solution was adopted. This system uses an open endodontic guide system that guides not the drill but the head of the contra-angle.
The technique using a closed guide has the disadvantage of preventing irrigation during the drilling phase, thus increasing the risk of accumulated dentin remnants and, probably, of metal debris due to drilling through the metal sleeve. Lack of irrigation will also cause both the drill and the tooth to heat-up. For this reason, it is important to advance gradually with the drill, millimetre by millimetre, stopping and rinsing in between the steps.
The 2ingis system enables irrigation during drilling and allows the use of any kind of bur, including small-diameter, long-necked round burs as well as diamond burs, which can create the access directly into the enamel.
On the other hand, the absence of a sleeve increases the risk of oscillation of the bur, as it rotates free. A study using the 2ingis system in implantology reported a mean deviation angle of 2.85°. It also described more precise deviations than with implant guides using sleeves (27).
An alternative to obtain a guided access in endodontics is a new dynamic three-dimensional technology. This freehand method works with an image-guided procedure merging CBCT data and a computer assisted software, guiding the high-speed handpiece and bur during the clinicals procedures. This technique could be the future of guided endodontics even if up to date, this kind of technology presents some limits for a full application in the Endodontic field such as the accuracy declared by the manufacturer companies of about 0.5 mm and the radiographic artifacts due to the presence of metal crowns (28).

## Conclusions

Endodontic treatment of a calcified tooth is a challenge for the dentist, even if equipped with a microscope, as the risk of intra-operative errors is very high (2). The precision of the GE technique seems to provide a valid alternative to endodontic surgery for the treatment of calcified canals. GE helps gain canal permeability reducing operative time respect to a freehand approach. The 2ingis system helps overcome the irrigation issue and leaves the clinician free to choose the bur to be used. This open endodontic concept appears to be better suited to endodontic interventions than closed guides.

## Clinical Relevance

This article describes several variations of the guided technique in the endodontic treatment of obliterated canals and highlights its advantages and limitations.

## Conflict of Interest

The authors declare they have no conflicts of interest.

## Acknowledgemets

The authors wish to thank Dr Cyril Perez for his contribution to the development of the technique, Dr Virginie Touboul for support in treating one of the clinical cases, and Asselin Bonnichon for developing the Cad-Cam technique for use in GE.

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