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# Guided Endodontics for Root Canals with Pulp Canal Obliteration

**Abstract:** Teeth with pulp canal obliteration leading to partial or complete occlusion of the root canal lumen can pose several technical challenges in location, negotiation and chemo-mechanical preparation. A guided endodontic technique can be an alternative approach to conventional methods. Three-dimensional data (CBCT and intra-oral surface scan) are aligned on a virtual planning software to position the appropriate endodontic drill within the root. A supporting guide is designed based the planned root canal access, which can be printed and used clinically to ensure the correct depth and angulation is maintained. This report provides an overview of static guided endodontics and discusses the implementation in managing teeth with pulp canal obliteration using clinical cases.

**CPD/Clinical Relevance:** Management of pulp canal obliteration of teeth with a static guided endodontic approach is relevant for clinicians. **Dent Update 2025; 52: 794-805**

The primary aim of root canal treatment (RCT) is to prevent or treat apical periodontitis through the prevention or control of infection within the root canal system.<sup>1</sup> This technical procedure is reliant on achieving access to the root canals to chemo-mechanically disinfect, shape and obturate with a biocompatible, retrievable and radiopaque material.<sup>2</sup> Poor treatment outcomes are often associated

when these stages are not successfully completed leading to post-treatment apical periodontitis.<sup>3,4</sup> The outcome of primary RCT is influenced by a number of prognostic factors and, when performed to guideline standards, peri-apical healed rates are in a range of 79–85%.<sup>5,6</sup>

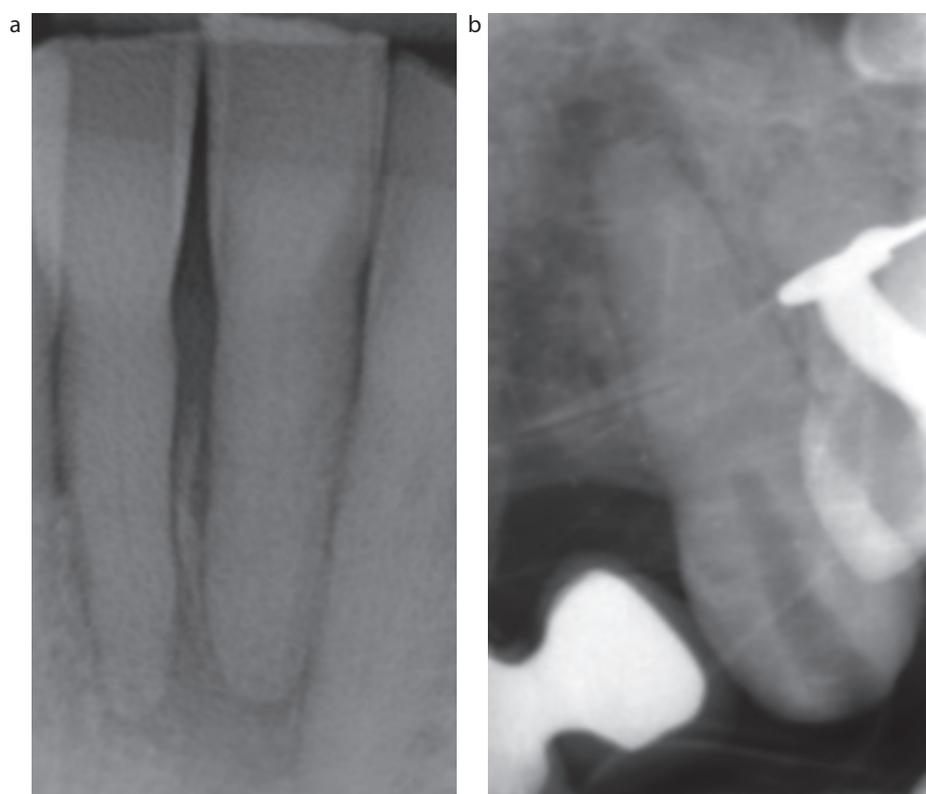
Canal irregularities can affect the ability to accurately locate and fully negotiate root canals, such as in the case

of pulp canal obliteration (PCO). Various conventional measures have been employed to help negotiate obliterated root canals; however, these depend on practitioner skill and experience. With the introduction of digital dentistry and guided implant surgery, a modern approach for managing obliterated/calcified canals uses guided endodontics. This article provides an overview of the application of guided endodontics to teeth affected by PCO.

## Pulp canal obliteration

Pulp canal obliteration (PCO), also referred to as calcific metamorphosis, results from an increased deposition of hard tissue within the root canal space, leading to partial or total occlusion of the canal lumen (Figure 1).<sup>7</sup> The exact mechanism remains unclear but is thought to be a reparative pulpal response following disturbance to the neurovascular supply.<sup>8</sup> The development

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**Figure 1.** Peri-apical radiograph showing (a) partial pulp canal obliteration and (b) total pulp canal obliteration.

of PCO can arise from physiological (age-related) changes or pathological causes, such as trauma, caries, vital pulp therapy or even orthodontic treatment.<sup>9</sup> PCO is a common sequela of dental trauma, namely with concussion and luxation injuries, with a reported incidence of 3.7–40%.<sup>10</sup> Development of PCO depends on trauma severity and stage of root development, with a higher preponderance in immature teeth.<sup>11</sup>

PCO progresses in a coronal-apical direction although, in root fracture injuries, the apical fragment may undergo canal obliteration alone.<sup>12</sup> It is often identified by incidental radiographic examination, which reveals narrow or diminished root canal space, normal periodontal ligament space and intact lamina dura.<sup>13</sup> It may be associated with yellow discoloration of the crown.<sup>7</sup> PCO is considered an indirect sign of pulp vitality and often unresponsive to sensitivity testing, which does not necessitate prophylactic RCT.<sup>9</sup> A complication of teeth with PCO is the development of pulp necrosis with peri-apical rarefactions, which may increase over the observation period.<sup>14</sup> The incidence of pulp necrosis in teeth with PCO is in a range of 1–27.2%.<sup>7,13,15</sup>

## Management

Teeth affected by PCO and apical periodontitis pose technical challenges for the practitioner in the location, negotiation and preparation of root canal(s). This may increase the risk of complications such as excessive dentine removal, root fracture, perforations and instrument separation.<sup>7,16,17</sup>

To alleviate the risk of iatrogenic errors, it is important to note the pulp chamber is centred in the tooth at the level of the cemento-enamel junction.<sup>18</sup> Modification of the access cavity entry point has been recommended at a site close to or through the incisal edge. This will permit straight-line access parallel to the long axis of the tooth, and the use of long-neck burs and ultrasonic tips will help avoid unnecessary dentine removal.<sup>19,20</sup>

The use of a dental operating microscope is invaluable for magnification and differentiating the darker dentine deposited in the pulp from the surrounding lighter root dentine.<sup>21</sup> An endodontic explorer probe (DG16 probe) is useful in locating and detecting the opening of small canal orifices. The use of dyes such as methylene blue,

which binds to organic material, can help with canal location. The classic ‘champagne’ test can be employed by applying 5% sodium hypochlorite in the pulp chamber and observing for the presence of bubbles emerging from the canal orifice, which correlates to oxygenation of the pulpal tissue.<sup>7</sup> Negotiation of sclerosed canals is usually undertaken with alternating size 6, 8 and 10 C+ files (Dentsply Sirona, Charlotte, North Carolina, USA) or K-files using a watch-winding motion with minimal apical pressure in a crown-down manner.<sup>7,13</sup>

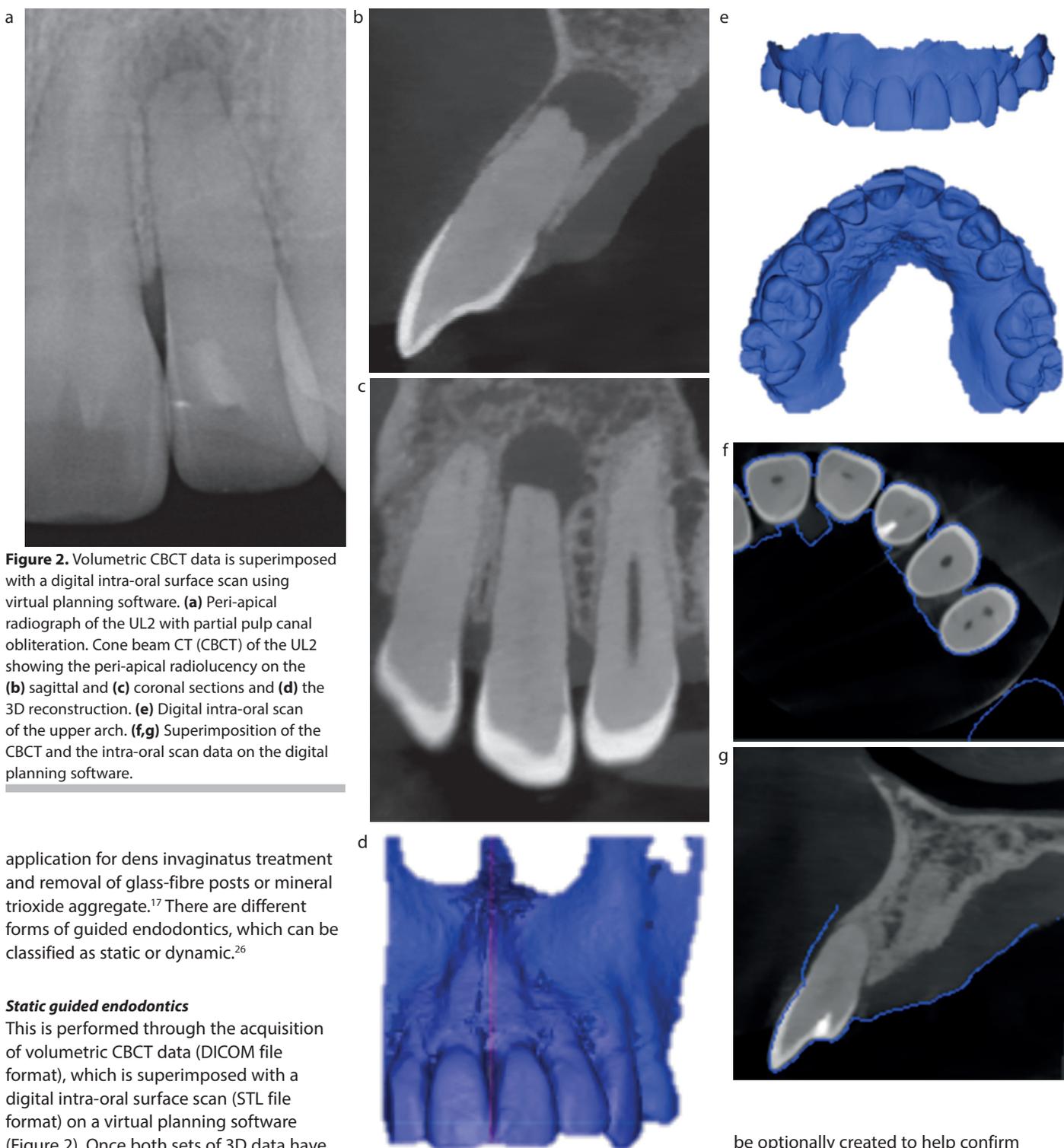
Two-dimensional radiographic images are subject to geometric distortion and anatomical noise, which can affect practitioner interpretation.<sup>22</sup> They also provide a limited view of the root. When working with 2D images, conventional access preparation may require multiple peri-apical radiographs to be taken at different angulations to determine orientation and progress in canal negotiation.<sup>23</sup> The use of cone-beam CT (CBCT) in cases of PCO helps to overcome these limitations and challenges through enhanced 3D imaging across different planes, and is more accurate and sensitive to detecting peri-apical disease and narrow pulp canals.<sup>22,24</sup>

Failure to adequately negotiate, disinfect and obturate the root canal via an orthograde approach may necessitate surgical endodontics or extraction with tooth replacement. Canal location may still pose a problem following root resection in the former option, and persistent apical inflammation may result from the escape of pockets of necrotic tissue rendered in the calcification process.<sup>7,13</sup> Surgical endodontics should be restricted to where *de novo* RCT or its re-treatment have resulted in post-treatment apical periodontitis or where there is absolutely no canal visible on a 3D CBCT scan.

Despite advances in 3D imaging, magnification and the use of piezo ultrasonic technology, conventional techniques remain challenging and time-consuming. They can often result in iatrogenic damage to the tooth, which will negatively impact the treatment outcome.

## Guided endodontics

An alternative technique to managing teeth with PCO is using guided endodontics to localize root canals in a minimally invasive approach.<sup>25</sup> Guided endodontics is becoming increasingly popular in endodontics owing to its broader



**Figure 2.** Volumetric CBCT data is superimposed with a digital intra-oral surface scan using virtual planning software. **(a)** Peri-apical radiograph of the UL2 with partial pulp canal obliteration. Cone beam CT (CBCT) of the UL2 showing the peri-apical radiolucency on the **(b)** sagittal and **(c)** coronal sections and **(d)** the 3D reconstruction. **(e)** Digital intra-oral scan of the upper arch. **(f,g)** Superimposition of the CBCT and the intra-oral scan data on the digital planning software.

application for dens invaginatus treatment and removal of glass-fibre posts or mineral trioxide aggregate.<sup>17</sup> There are different forms of guided endodontics, which can be classified as static or dynamic.<sup>26</sup>

#### **Static guided endodontics**

This is performed through the acquisition of volumetric CBCT data (DICOM file format), which is superimposed with a digital intra-oral surface scan (STL file format) on a virtual planning software (Figure 2). Once both sets of 3D data have been correctly aligned, the access cavity entry point and apical preparation length can be planned by selecting the correct endodontic guided drill based on the tooth length (Figure 3).<sup>27</sup> Steco-system-technik (Hamburg, Germany) endodontic drills are available in two lengths (20 mm and 28 mm) with a width of 0.9 mm, which has a corresponding metal sleeve with an internal diameter of 1mm, and is 5 mm in height. The drill tip is placed where

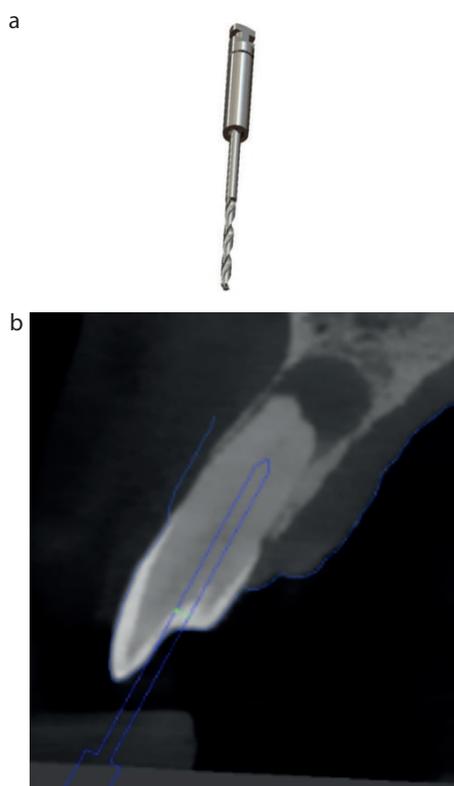
it reaches the visible portion of the root canal or the apex when no root canal can be ascertained. A virtual sleeve is selected based on the width of the endodontic guided drill and positioned above the occlusal surface (Figure 4).

A virtual template is designed to create a stable guide using supporting teeth to permit drilling (Figure 5). Windows can

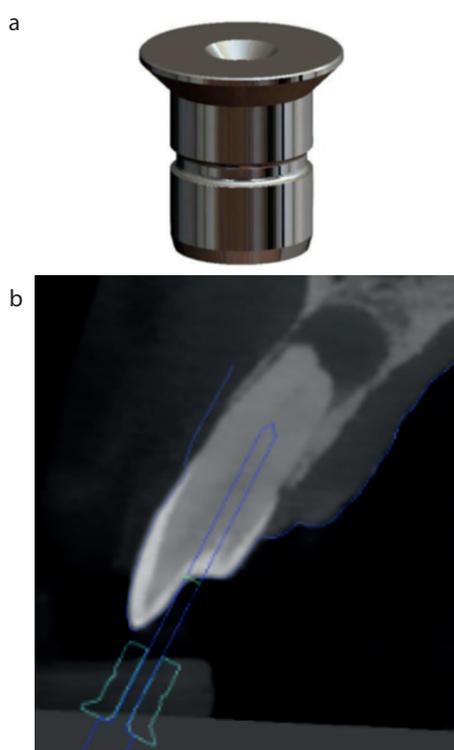
be optionally created to help confirm correct seating of the guide intra-orally (Figure 6). Once the design has met these requirements, it can be exported for 3D printing (Figure 7).

The guide is transferred to the patient to assess for fit, and rubber dam isolation is ideally performed before endodontic access.

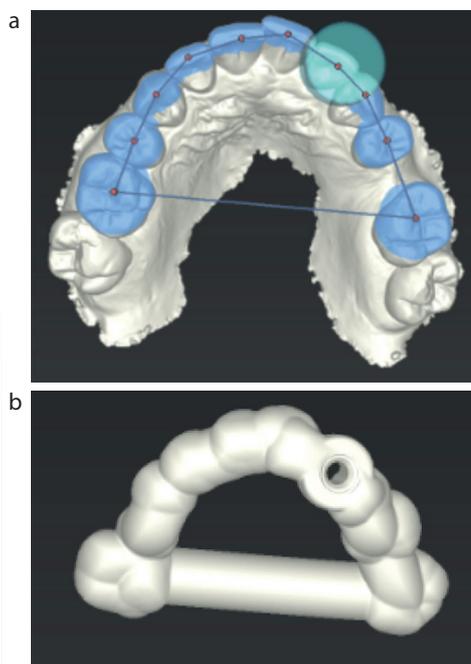
Initial access is gained with a diamond bur in a fast handpiece; the entry point planned digitally acts as an additional guide. Attempts to negotiate the canal



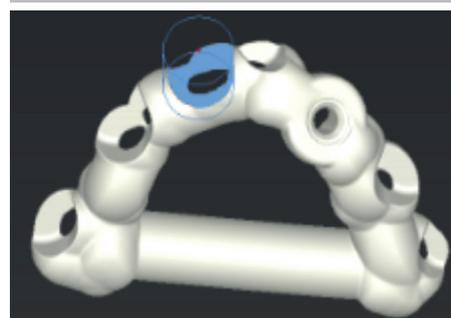
**Figure 3.** Access cavity entry point and apical preparation length are planned using an endodontic guided drill. **(a)** Selection of appropriate length of endodontic guided drill. **(b)** Orientation of the guided drill for the proposed access cavity entry point.



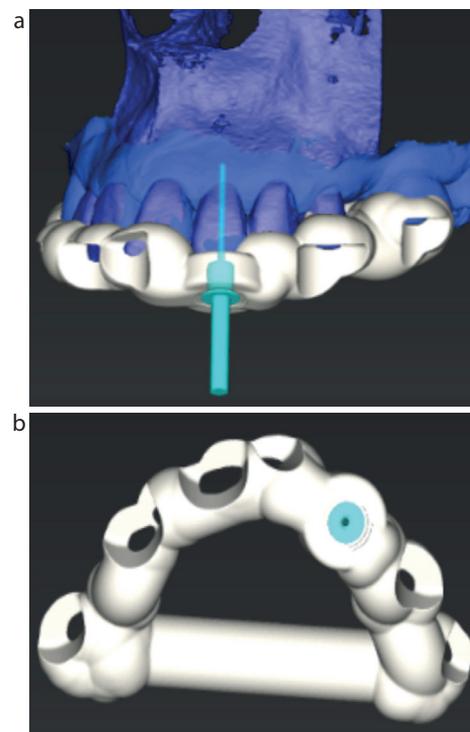
**Figure 4.** **(a,b)** Selection and positioning of a corresponding sleeve relative to the guided drill width.



**Figure 5.** Virtual template to create a stable guide to permit drilling **(a)** Designing the coverage of the endodontic guide using teeth for support and retention. **(b)** Output from the computer design process.



**Figure 6.** Inspection windows can be created to help with visualizing seating of the guide intra-orally, which produces the final design guide.



**Figure 7.** Final guide design on the cone beam CT 3D reconstruction, which can be exported to be 3D printed.

of interest.<sup>17</sup> With certain systems, these reference markers can also be planned digitally.<sup>9</sup> A stereo camera is connected to a dynamic navigation system, which enables real-time 3D spatial feedback on the drill path and angulation. This enables the practitioner to correct any deviation from the planned path instantly.<sup>17,26</sup>

Dynamic guided endodontics still requires further research and development before it can be used in everyday practice.

### Case reports

The following clinical cases describe the implementation of static-guided endodontic access for the management of teeth with partial and total PCO.

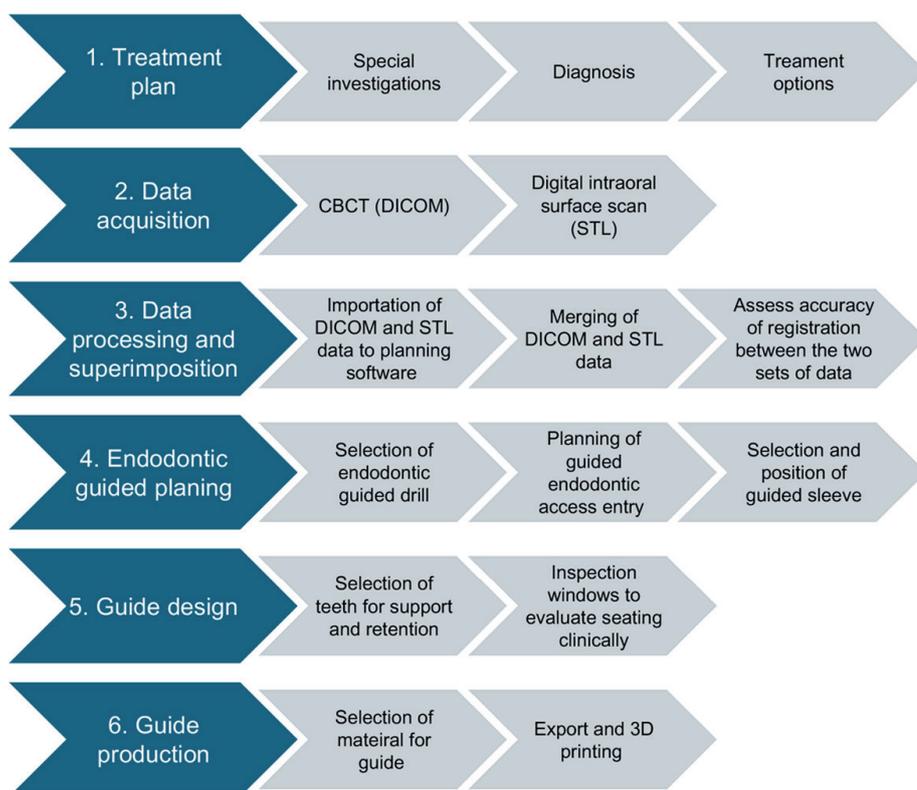
#### Case 1: total PCO

A 16-year-old male patient was referred for RCT of the UL1 and UL2 after sustaining trauma 6 years ago, which resulted in avulsion and loss of the UR1. RCT had previously been attempted on the UL2 by the patient's general dentist. The patient presented asymptotically and was seen in a joint restorative-orthodontic clinic for space management and rehabilitation.

are made after every 2 mm in depth with small K- or C+ files. This process is repeated until the mechanical stop on the drill contacts the sleeve, indicating the apical target depth has been reached.<sup>9</sup> Once the canal has been negotiated, RCT is undertaken in the usual manner. Figure 8 illustrates the digital workflow for static-guided endodontics.

#### Dynamic guided endodontics

Similar to the above technique, the dynamic endodontic guided access is ideally planned using virtual planning software. Dynamic guided endodontics uses CBCT data with predetermined intra-oral reference markers placed on the contralateral side of the tooth



**Figure 8.** Flowchart illustrating the digital workflow for static guided endodontics.



**Figure 9. Case 1.** Presentation at first visit.

At the initial visit, both the UL1 and UL2 were negative to percussion and sensitivity testing. No intra-oral swellings or sinuses were noted (Figure 9).

Peri-apical radiolucencies were associated with the UL1 and UL2 with evidence of total PCO of the UL2 (Figure 10).

The endodontic diagnosis of the UL1 and UL2 was pulp necrosis and asymptomatic apical periodontitis.

#### Management

Both the CBCT and intra-oral surface scan data were merged using the coDiagnostiX (Chemnitz, Germany) planning software. Owing to the extent of the obliteration, a 28-mm endodontic drill (Steco-system-technik) was chosen with the drill tip planned to the apex (Figure 11).

The fit of the endodontic guide was assessed before access cavity preparation was started under a rubber dam (Figure 12). Endodontic drilling was performed in 2-mm increments, and the guide was continuously checked to ensure it was fully seated.

A 'check' peri-apical radiograph was taken once half the drill length was reached (Figure 13). Throughout the drilling course, it was periodically confirmed no patent canal could be negotiated with small C+ files (Dentsply Sirona). Once the drill length had been reached, apical patency was established. Access cavity preparation was started on the UL1 on the same visit, and both teeth were chemo-mechanically debrided using 3% sodium hypochlorite and K-files using a step-back technique. The master apical files for UL1 and UL2 were ISO 60 and ISO 80 respectively, and an apical plug was placed using mineral trioxide aggregate (Figure 14). Backfilling of the remaining canal space with thermoplasticized gutta-percha was undertaken and glass-ionomer restorative material was placed over the canal orifice, and the remaining access cavity restored with composite resin (Figure 15).

#### Case 2: partial PCO

A medically fit and well 31-year-old man who had sustained trauma 15 years ago was referred for RCT of the UR1 following two failed attempts of canal negotiation by an endodontic specialist. The patient complained of pain on biting and did not have any aesthetic concerns.

At presentation, the UR1 was tender to buccal palpation and negative to percussion testing. The crown had a mild yellow iscolouration.

A peri-apical radiolucency was associated with the UR1, and there was evidence of partial PCO with patent root canal space within the apical third (Figure 16).

The endodontic diagnosis of the UR1 was pulp necrosis and asymptomatic apical periodontitis.

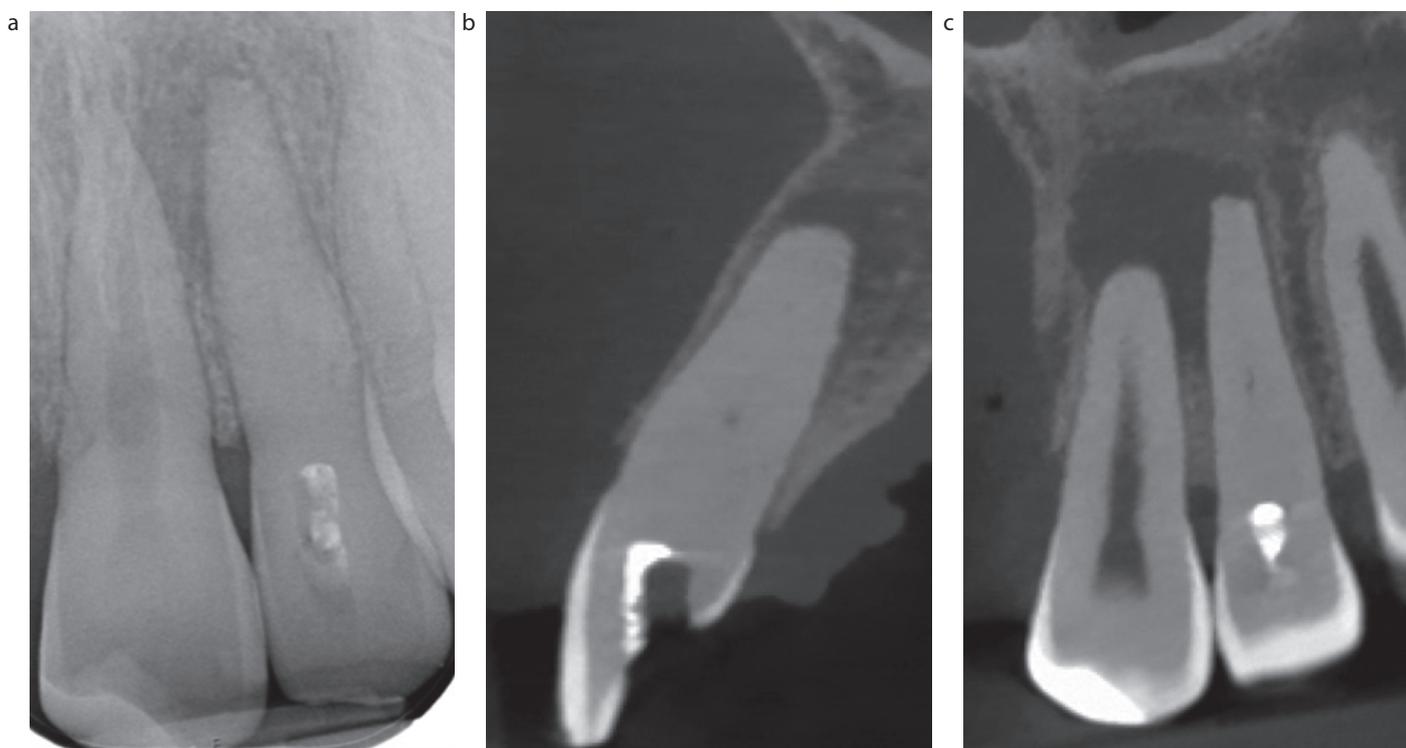
#### Management

The digital workflow for endodontic guided access described in Case 1 was followed. In this case, rubber dam isolation was initially not used for endodontic access to ensure correct seating of the guide and to allow assessment of the orientation of the drill relative to the tooth axis. The drilling extent was planned up to the start of the canal space in the apical third, which involved a working length of 22 mm. A 28 mm length drill was selected, and a rubber stop was placed to correspond to the planned drill working length (Figure 17).

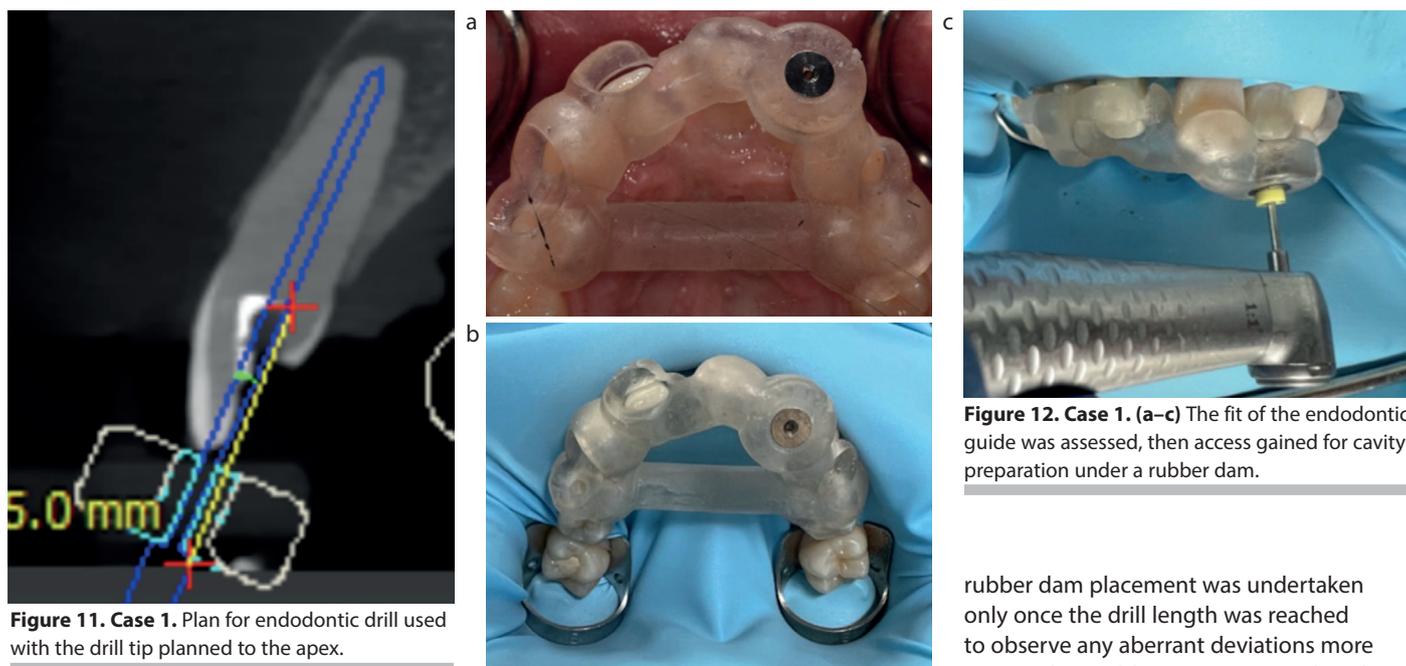
Once the drill working length was reached, single tooth rubber dam isolation was undertaken and a peri-apical radiograph revealed the canal had been transported distal to the apical canal (arrowed) (Figure 18). The canal was successfully negotiated using hand instrument files using a watch-winding motion (Figure 19). Following the establishment of the new working length, chemo-mechanical preparation was completed using 3% sodium hypochlorite and ProTaper Gold (Dentsply Sirona) rotary files. Owing to the distal canal transportation, a warm vertical obturation technique using gutta-percha and a calcium-silicate bioceramic sealer was chosen (Figure 20).

#### Case 3: partial PCO and root resorption

A 46-year-old woman with a history of trauma 20 years ago was referred for root canal treatment of the LL3.



**Figure 10. Case 1. (a–c)** Peri-apical radiolucencies were associated with the UL1 and UL2 with evidence of total pulp canal obliteration of the UL2.



**Figure 11. Case 1.** Plan for endodontic drill used with the drill tip planned to the apex.

**Figure 12. Case 1. (a–c)** The fit of the endodontic guide was assessed, then access gained for cavity preparation under a rubber dam.

At presentation, the LL3 was unrestored and positive to percussion testing and negative to sensibility testing.

A peri-apical radiolucency was associated with the LL3, and there was evidence of partial PCO with root canal space present within the mid-root third. At mid-root level, an oval radicular radiolucency confined to the root canal space was present, which indicated internal root resorption (Figure 21).

Endodontic diagnosis of the LL3 was pulp necrosis with symptomatic apical periodontitis.

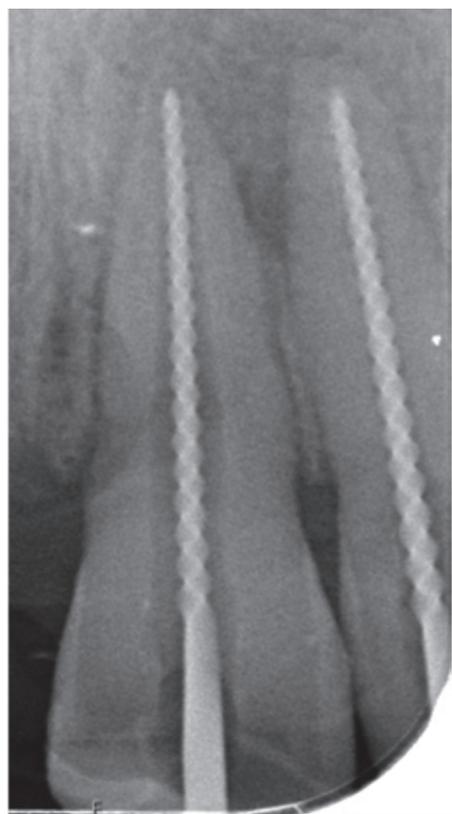
**Management**

The same digital workflow was implemented for planning guided access for the LL3 up to the level of the resorptive defect – a working length of 22 mm from the sleeve (Figure 22). Similarly to Case 2,

rubber dam placement was undertaken only once the drill length was reached to observe any aberrant deviations more accurately. A rubber stopper was placed on the endodontic drill, and access through the incisal edge was performed as described in the above cases (Figure 23). During access preparation, there was mesio-lingual deviation of the drill; drilling was stopped and K-files used to scout and negotiate the canal (Figure 24). The deviation may have been minimized by localized removal of the enamel over the access entry point to allow the guided drill a more defined entry path through the dentine.

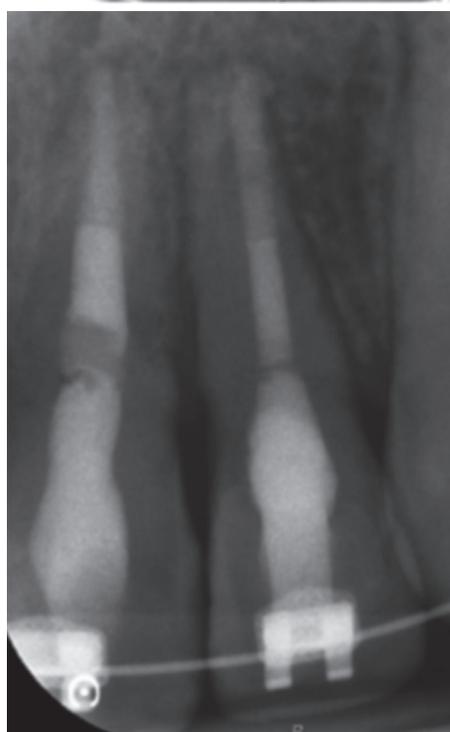


**Figure 13. Case 1.** A 'check' peri-apical radiograph taken when half the drill length had been reached.



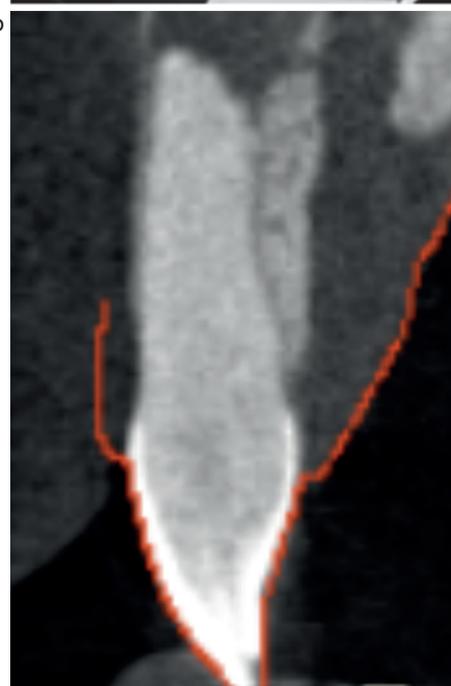
**Figure 14. Case 1.** Apical files in UL1 and UL2.

Other factors for deviation should also be evaluated, such as the fit accuracy of



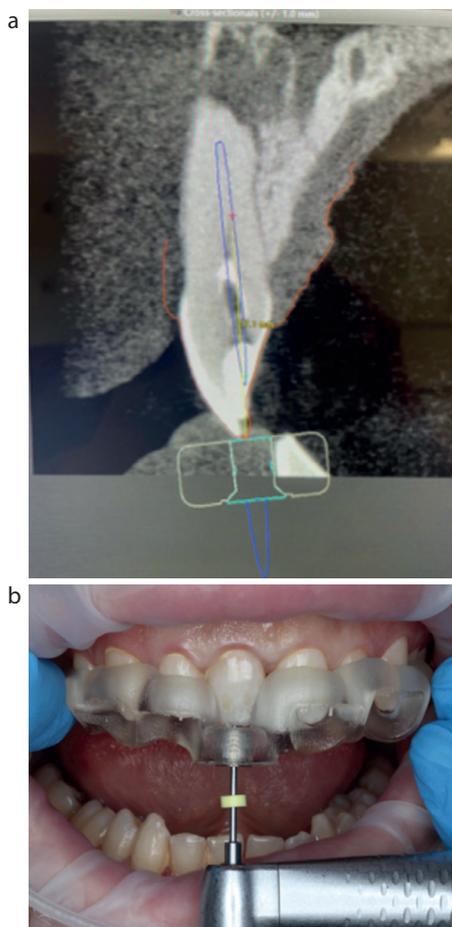
**Figure 15. Case 1. (a,b)** Canal space backfilled with thermoplasticized gutta-percha, glass ionomer cement placed over the canal orifice and remaining access cavity restored with composite resin.

the guide and sleeve, the distance of the sleeve to the access entry point and the planned drill length. Chemo-mechanical preparation was completed using 3% sodium hypochlorite and ProTaper Gold



**Figure 16. Case 2.** Peri-apical radiolucency associated with the UR1; evidence of partial pulp canal obliteration with patent root canal space within the apical third.

rotary files. A warm vertical obturation technique was adopted with a calcium hydroxide sealer (Sealapex, Kerr, Brea, California, USA) and backfilling with thermoplasticized gutta-percha. The gutta-percha and the lateral iatrogenic deviation were sealed with glass-ionomer restoration and the tooth restored with composite resin (Figure 25).



**Figure 17. Case 2.** (a,b) Drilling extent was planned up to the start of the canal space. A 28-mm length drill was selected, and a rubber stop placed.

### Case 4: partial PCO

A 48-year-old man was referred by the patient's general dentist for root canal treatment of the UL1 following an incidental finding of a peri-apical rarefaction.

At presentation, the UL1 was negative to percussion testing and minimally restored.

A peri-apical radiolucency was associated with the UL1, and there was evidence of partial PCO with root canal space within the mid and apical thirds (Figure 26).

The endodontic diagnosis of the UL1 was pulp necrosis with asymptomatic apical periodontitis.

#### Management

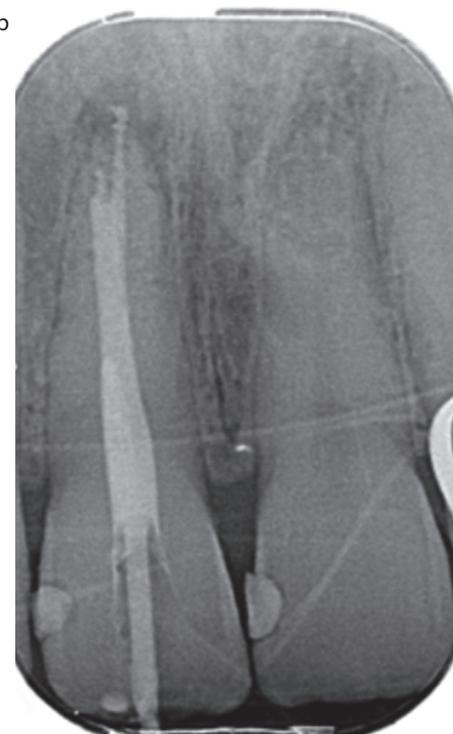
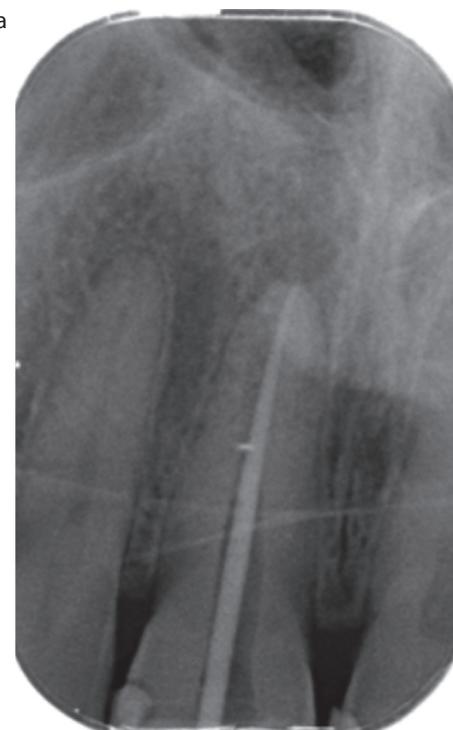
The digital workflow for guided endodontic access was applied to the UL1 with access extended up to the mid-root level (Figure 27). Endodontic



**Figure 18. Case 2.** Peri-apical radiograph showing the canal transported distal to the apical canal (arrowed).



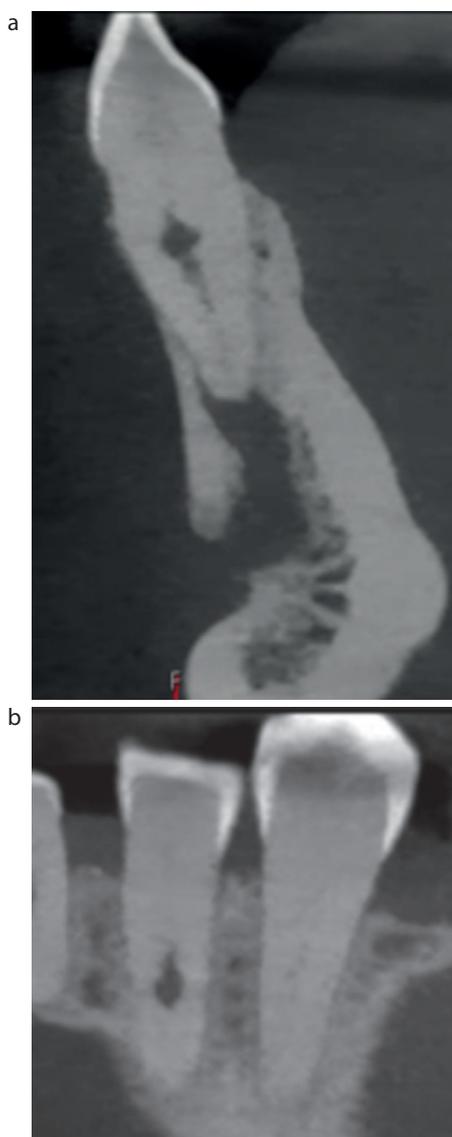
**Figure 19. Case 2.** Canal negotiated using hand instrument files.



**Figure 20. Case 2.** (a,b) Warm vertical obturation using gutta-percha and a calcium-silicate bioceramic sealer.

access was performed under rubber dam conditions, and a 21-mm endodontic drill was selected to create the path of entry. This allowed small K-files to negotiate the canal to establish working length (Figure 28). Chemo-mechanical

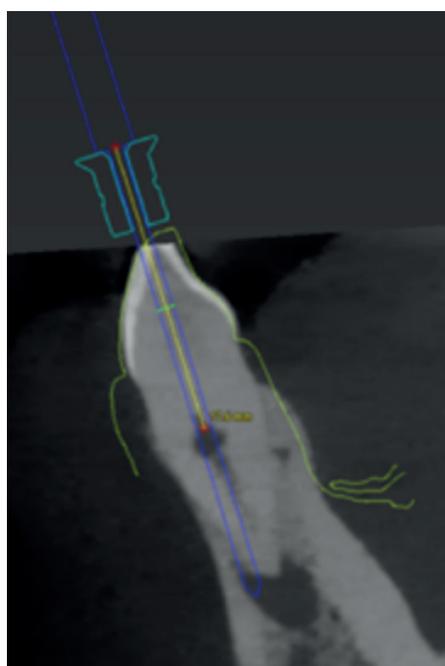
preparation was completed using 3% sodium hypochlorite and ProTaper Gold rotary files. The obturation technique and restorative materials used in Case 3 were employed (Figure 29).



**Figure 21. Case 3.** (a) Peri-apical radiolucency was associated with the LL3, with evidence of partial pulp canal obliteration. (b) An oval radicular radiolucency in the root canal space indicated internal root resorption.

### Discussion

The use of static-guided endodontics to treat teeth with obliterated root canals has been demonstrated to be a relatively safe, reliable and effective treatment modality.<sup>28</sup> One of the main problems encountered is tangential deviation from the planned drill path. Zehnder *et al* demonstrated a mean angle of deviation of 1.81° from the planned and prepared access cavities.<sup>25</sup> In addition, Buchgreitz *et al* demonstrated small deviations (0.46mm at the drill tip) between the planned and performed drill paths are below the risk threshold when using a guide rail concept.<sup>29</sup> These deviations can



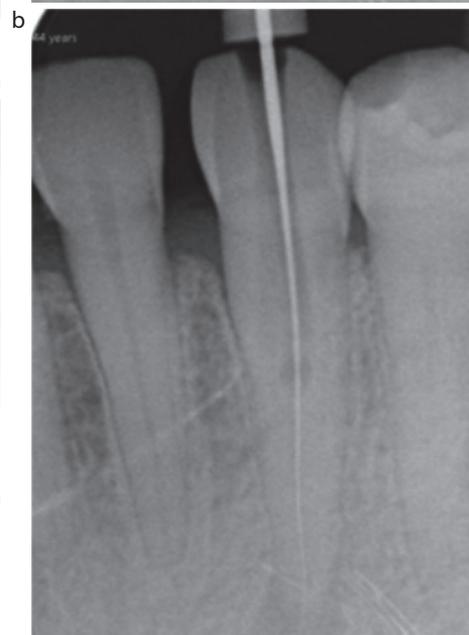
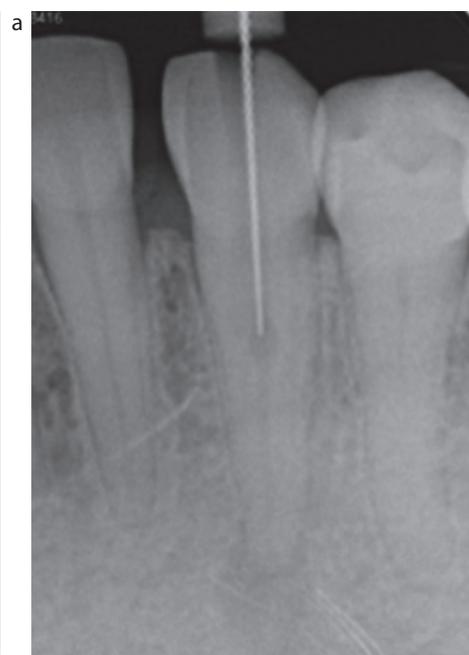
**Figure 22. Case 3.** Guided access planned up to the level of the resorptive defect.



**Figure 23. Case 3.** A rubber stopper was placed on the endodontic drill, and access gained through the incisal edge.

be explained by the reduction in control of the tip of the drill as distance away from the sleeve increases. Similar to guided dental implant surgery, drill deviation has been shown in several studies, and the greater the distance from the sleeve the tip has to travel, the greater the deviation.<sup>30</sup> Some deviations can be classified as 'acceptable' regarding precision when the canal can still be located and chemo-mechanically prepared.<sup>31</sup> In other cases, deviations can lead to iatrogenic damage such as ledges, transportation of the canal and perforations.

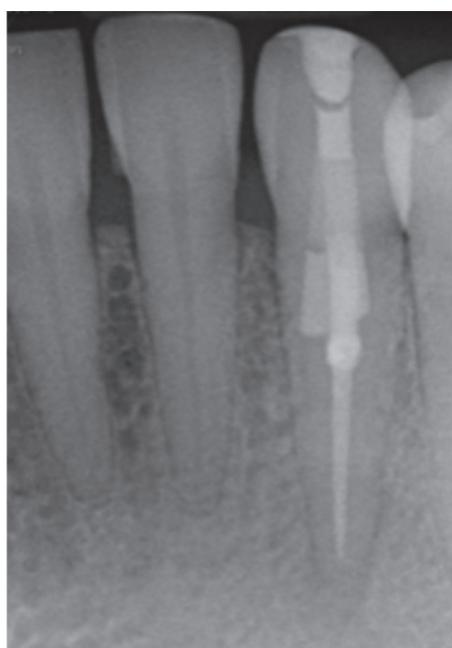
Angular and linear deviations were found to be higher among guided access cavity preparation for molar teeth compared to anterior and premolar teeth, which may be owing to interference from opposing teeth.<sup>32</sup> To avoid the risk of



**Figure 24. Case 3.** (a,b) Drilling was stopped after a mesio-lingual deviation was made, and K-files used.

perforation, a staggered drilling protocol can be adopted, checking the drill path every 2–3mm and verifying the orientation with peri-apical radiographs at specific depths or when concerned. An alternative approach would be to use a shorter drill to improve control. However, drill lengths are predetermined by manufacturers and not custom designed.

In comparison with conventional endodontic access, the guided approach has been shown to improve canal location,



**Figure 25. Case 3.** The canal and the lateral iatrogenic deviation were sealed with glass ionomer restoration and the tooth restored with composite resin.

reduce substance loss and be more efficient. Some authors suggest that success in the guided approach was not influenced by operator experience.<sup>33</sup> However, there is certainly a learning curve in using a guided approach in endodontics. The preservation of tooth structure with the guided approach means retaining more cervical dentine, which improves fracture strength of teeth compared to traditional or conventional access cavity approaches.<sup>34</sup> One potential concern is that the endodontic drill used in the above cases does not have a progressive taper and thus does not follow the anatomy of the normal root canal space. Therefore, the drills have the potential to be destructive and remove unnecessary dentine, particularly in the apical third, where the root width is narrowest. It is vital to continually strive to gain patency conventionally in periodic intervals with this treatment approach, as demonstrated in the above cases.

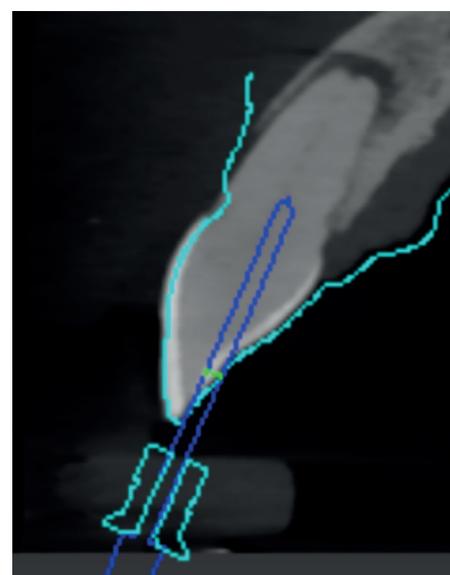
Static guided endodontics has been shown to be successful in locating calcified canals and the root apex to a high degree of precision compared to conventional strategies.<sup>28,35,36</sup> There are no longitudinal studies evaluating peri-apical healed rates or survival of teeth with PCO managed with guided endodontics. Successful application of guided endodontics should still abide by the biological aims of root canal treatment



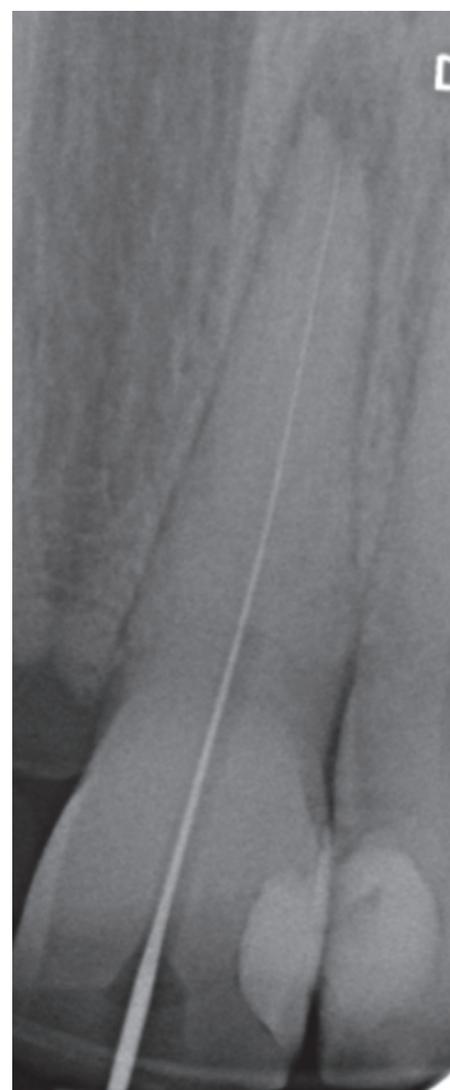
**Figure 26. Case 4. (a,b)** Peri-apical radiolucency was associated with the UL1, with evidence of partial pulp canal obliteration.

in terms of chemo-mechanical disinfection and achieving patency via the anatomical apical terminus. Inferences can be drawn that similar peri-apical healed rates and survival in the absence of iatrogenic errors should align with root canal treated teeth without PCO.

Despite guided endodontics showing much promise in managing these complex cases, the procedure can be performed only



**Case 4. Figure 27.** The digital workflow for guided endodontic access was applied, with access extended up to the mid-root level.



**Figure 28. Case 4.** Small K-files used to negotiate the canal to establish working length.



**Figure 29. Case 4.** Post-obturation radiograph of the UL1. Access cavity restored with composite resin.

in straight roots or the straight portion in curved canals, requires time for planning, increased radiation doses for CBCT and additional lab costs for guide production.<sup>9</sup> With the uptake of guided endodontics, it would be ideal if a wide range of endodontic drills of different lengths and diameters became commercially available, which would further help improve accuracy and tooth preservation.

Dynamic navigation systems demonstrate merit in detecting root canals more accurately.<sup>37</sup> Nevertheless, they have been found to have comparable angular deviation (1.7°) to static-guided endodontics.<sup>38</sup> Access cavities were shown to be more precisely prepared and less time was required to locate the canal.<sup>39</sup> The main disadvantages of dynamic guided endodontics are the need to practise access cavity preparation and that some of the systems in use are bulky and difficult to use.<sup>9</sup>

## Conclusion

Static-guided endodontics is a minimally invasive technique in managing teeth with apical periodontitis secondary to PCO. With the advancement of the digital workflow in implant surgery, clinicians can apply these principles in planning endodontic cases to facilitate access and chemo-mechanical preparation. Digital workflows can be used to avoid excessive preparation and prevent iatrogenic errors; however, the employment of core principles of conventional endodontics should not be understated in cases using digital technology. Finally, further research is required to enhance guided endodontics' accuracy and applicability.

## Compliance with Ethical Standards

**Conflict of Interest:** The authors declare that they have no conflict of interest.  
**Informed Consent:** Informed consent was obtained from all individual participants included in the article.

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