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Guided Endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology

CASE REPORT

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Abstract – *Aim*: To present a new treatment approach for teeth with pulp canal calcification (PCC) which require root canal treatment. *Case*: A 15-year-old male patient presented with pain of his upper right central incisor. The tooth showed signs of apical periodontitis. Due to PCC, location of the root canal was judged to be difficult and associated with a high risk of perforation. A cone beam computed tomography (CBCT) and an intraoral surface scan were performed and matched using software for virtual implant planning. After planning the position of the drill for root canal location, a virtual template was designed, and the data were exported as an STL file and sent to a 3D printer for template fabrication. The template was positioned on the anterior maxillary teeth. A specific drill was used to penetrate through the obliterated part of the root canal and obtain minimally invasive access to the apical part. The root canal was accessible at 9 mm distance from the apex. Further root canal preparation was carried out using an endodontic rotary instrumentation system. After an interappointment dressing for 4 weeks, the root canal was filled with vertically condensed gutta-percha using an epoxy sealer. The access cavity was restored with a composite material. After 15 months, the patient was clinically asymptomatic with no pain on percussion. The radiograph showed no apical pathology. *Conclusions*: The presented guided endodontic approach seems to be a safe, clinically feasible method to locate root canals and prevent root perforation in teeth with PCC.

It is well documented that luxation injuries affect both the periodontium and the pulp (1). The fate of the pulp tissue varies according to the intensity of the injury and the stage of root development (2). Extensive physical trauma may result in either partial or total rupture or stretching of the neurovascular supply to the pulp at the apical foramen. Thus, pulp necrosis is a frequent event, especially in teeth with completed root formation (3).

In immature teeth, however, revascularization and reinnervation of the pulp may occur in the absence of infection, if the size of the apical foramen is sufficiently great to allow vascular ingrowth.

If the revascularization process is successful or in cases of milder injuries with pulp survival after the trauma, regressive pulp changes can occur and may result in accelerated apposition of new hard tissue in the root canal (4).

This process usually starts in the coronal portion of the root canal and is followed by gradual narrowing of the pulp space (5).

The greatest frequency of PCC in immature teeth is encountered among lateral luxations (71%) followed by extrusions (61%). In intrusion cases, pulp necrosis is the predominant healing complication (4). PCC is considered as a sign of pulpal healing and does not require any endodontic intervention – regardless of the result of the pulp sensitivity test (6, 7).

From an aesthetical point of view, yellow crown discoloration, which is frequently associated with PCC, can be successfully treated with external bleaching or placement of a veneer (8).

In the initial phase of PCC, particularly during the first 3 years, apical pathology is very unlikely. However, the development of pulp necrosis and periapical changes may occur as a late complication after several uneventful years (9). Secondary pulp necrosis after PCC indicated by periapical bone lesions was reported in 7–27% of the cases and seems to increase with longer observation periods (4, 7, 10, 11).

It is well accepted that in teeth showing radiographic signs of periapical disease, root canal treatment is indicated (12). However, in teeth with PCC, this can be a challenging task. Although a histologic examination of teeth with PCC usually shows a persisting narrow root canal and although morphological differences between the hard tissue formed after the injury and normally formed dentin are present (13), determining the correct location of the root canal is difficult (14). The use of a microscope is recommended in these cases (15). Nevertheless, excessive loss of tooth structure and a high risk of perforation may considerably impair the prognosis of the affected tooth (16).

This case report describes a new method to locate an obliterated root canal in a tooth with PCC and periapical pathology.

Case report

A 15-year-old male patient presented in January 2014 with pain of his upper right central incisor. He had a history of trauma 7 years prior to the upper anterior region.

The clinical examination revealed a slightly discoloured upper right central incisor (Fig. 1). The tooth was tender to percussion and a negative response was elucidated with both cold and electric pulp testing. The periapical radiograph revealed a completely obliterated pulp chamber and pulp canal (Fig. 2). The periapical area of tooth 11 was difficult to interpret. A CBCT (Morita Accuitomo 80; J. Morita Mfg. Corp., Irvine, CA, USA) was performed to allow a more detailed view of the periapical area. The CBCT showed clear signs of apical periodontitis. The measured length of the tooth from the incisal edge to the radiographic apex was approximately 24.4 mm. The root canal was only visible in the apical third of the root at a distance of approximately 7.7 mm from the apex (Fig. 3).

To enable a guided location of the root canal in the apical third, a 3D printed template was used. For fabrication, the following steps were undertaken.

An intra-oral scan was performed (iTero, Align Technology Inc., San Jose, CA, USA) and uploaded into a software for virtual implant planning (coDiagnostiX™

Fig. 1. Slight, hardly visible discoloration of the maxillary right central incisor secondary to trauma.

Fig. 2. Radiograph of the same tooth showing almost complete PCC and a widened periodontal ligament space at the periapex.

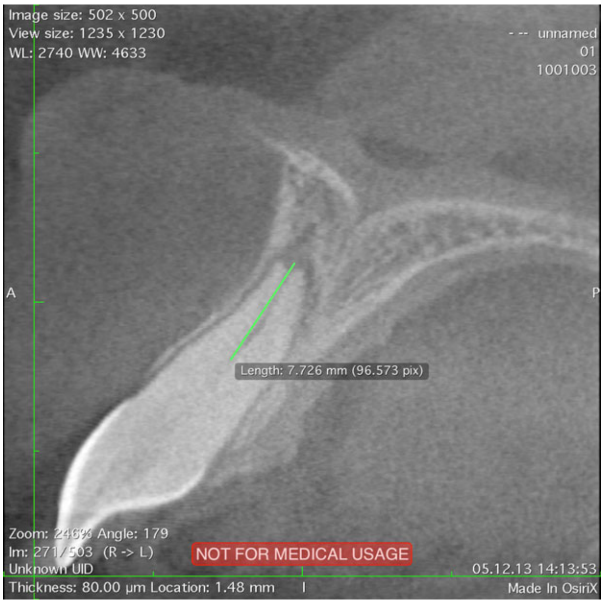

Fig. 3. CBCT showing apical periodontitis and PCC. The root canal is visible in the apical part of the root.

Version 9.2; Dental Wings Inc., Montreal, Canada). After the additional upload of the CBCT, both the CBCT and the surface scan were matched based on radiographically visible structures, for example the teeth of the patient. The drill, which was used, for guided endodontics (Straumann Drill for Tempimplants, Ref.: 80381; Institut Straumann, Basel, Switzerland) with a total length of 37 mm, a working length of 18.5 mm and a diameter of 1.5 mm (Fig. 4) was virtually designed by applying the implant designer tool of the coDiagnostiX software and virtually superimposed to the root canal. The axis of the drill was angled in such a way that the tip of the extended drill would reach the radiographically visible apex of the tooth (Fig. 5). After planning the position of the drill, a virtual template was designed applying the template designer tool of the CODIAGNOSTIX software (Fig. 6). As for the drill, a guiding sleeve (2.8 mm external diameter, 1.5 mm internal diameter and 6 mm length) was customized due to a software tool and virtually incorporated into the planification prior to the template creation.

The virtual template was exported as an STL file and send to a 3D printer (Objet Eden 260 V, Material: MED610, Stratasys Ltd., Minneapolis, MN, USA). Computerized numerical control (CNC) technology was used to fabricate the designed sleeve, which was integrated into the printed template to guide the drill during cavity preparation (Fig. 7).

Root canal treatment was started without anaesthesia under rubber dam. The template was positioned on the anterior maxillary teeth and its correct and reproducible fitting was checked (Fig. 8). A mark was placed through the template sleeve to indicate the exact region of the endodontic access cavity. In the present case, the cavity was extended up to the incisal edge to allow for straight-line access, parallel to the long axis of the tooth for the drill. Enamel was removed in this area using a diamond bur until dentine was exposed.

Then, the specific drill was used at 10000 RPM with pumping movements to penetrate through the calcified part of the root canal and gain access to the apical region. The drill was cleaned regularly of its debris during preparation. Irrigation was performed with 1% sodium hypochlorite. After each 2 mm gain in depth, a K-file size 10 (VDW, Munich, Germany) was used to check whether the root canal could be negotiated at that depth. This was possible at 9 mm distance from the apex, approximately 1 mm before reaching the apical target point. Using the described technique, location of the root canal and further negotiation up to the apex was possible in less than 5 min (Fig. 9).

Fig. 4. Special drill used for root canal location.

Working length determination was carried out using a combination of apex locator (Raypex 5, VDW, Munich, Germany) and radiography (Fig. 10). Root canal preparation was carried out using an endodontic rotary instrumentation system (Mtwo, VDW, Munich, Germany) up to a 50/.04 file. Sodium hypochlorite (1%) was used for irrigation. After drying the root canal with paper points, a calcium hydroxide interappointment dressing (Ultracal XS; Ultradent Products Inc., South Jordan, UT, USA) was placed. The access cavity was sealed with Cavit™ (3M ESPE, Seefeld, Germany). After 4 weeks, the root canal was filled with vertically condensed gutta-percha (BeeFill, VDW, Munich, Germany) using an epoxy sealer (AH plus, De Trey, Konstanz, Germany). The obturation material was reduced 1 mm below the CEJ. The access cavity was cleaned and restored with a composite material (Filtek Supreme XTE, 3M ESPE, Seefeld, Germany) in conjunction with a multistep bonding agent (Optibond FL, Kerr, Orange, CA, USA).

After root canal filling (Fig. 11), the patient was clinically asymptomatic with no pain on percussion. Fifteen months after definitive treatment, the patient was still free of clinical symptoms. There was no sensitivity to percussion, and probing depths on all sites were ≤3 mm. The radiograph showed no signs of apical pathology (Fig. 12).

Discussion

This case report describes a new method to facilitate root canal treatment in teeth with PCC and apical periodontitis. Such cases with radiographically invisible root canals are classified in the highest difficulty level by the American Association of Endodontists due to the fact that a predictable treatment outcome may be challenging for even the most experienced practitioner (17). Considering that up to one-quarter of all teeth with post-traumatic PCC may develop apical pathology in long term, thus warranting endodontic intervention, this topic has a high clinical relevance (11).

At first glance, the presented approach seems to be far from daily routine. The expenditure required for three-dimensional planning and fabrication of the template was high. However, chair time for the root canal treatment was considerably reduced, and a perforation was prevented. These benefits may justify the additional cost. Compared to further therapy costs needed if conventional endodontic treatment fails and leads to tooth loss, the presented approach may be regarded as a cost-effective intervention.

Considering the fast-paced digitization of dentistry during the last years, it is likely that combining the information obtained from CBCTs and digital impressions will become standard in the future. Thus, provided that a reasonable therapy workflow is established, there is a realistic chance for implementing this treatment approach in daily routine practice.

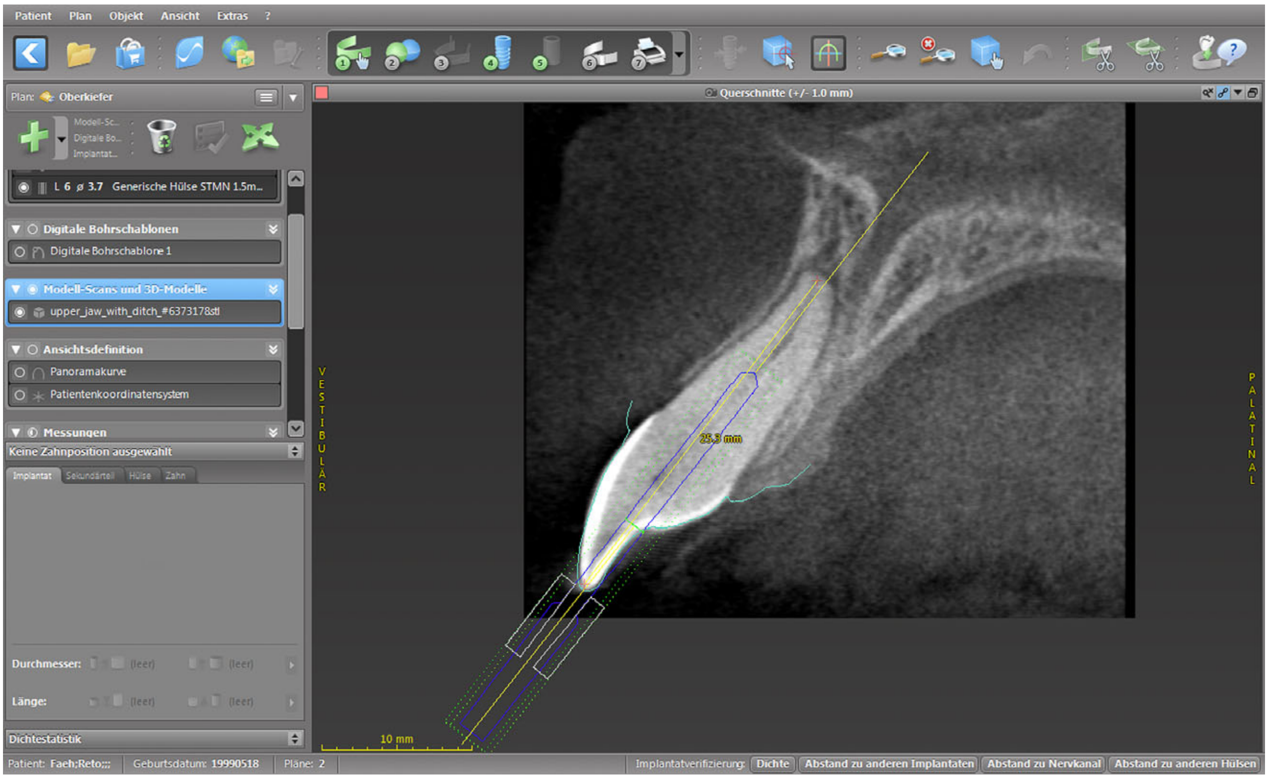

Fig. 5. Drill virtually superimposed to the root canal in the planning software.

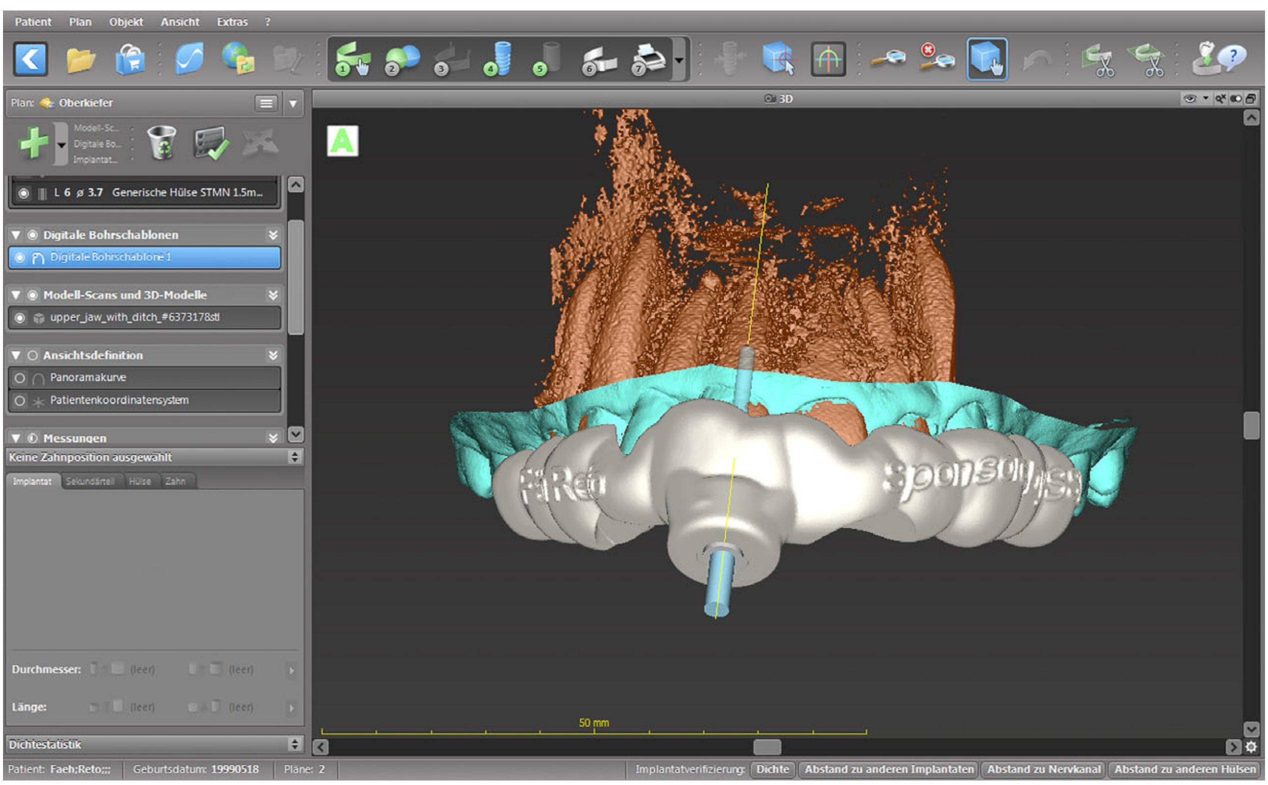

Fig. 6. Virtually designed template.

However, this endodontic intervention is mainly restricted to anterior teeth due to their ideal accessibility for the guiding template.

In implantology, guided surgery techniques have already gained wide acceptance. Templates are either manually fabricated in a dental laboratory or

Fig. 7. Printed template with included metal sleeve.

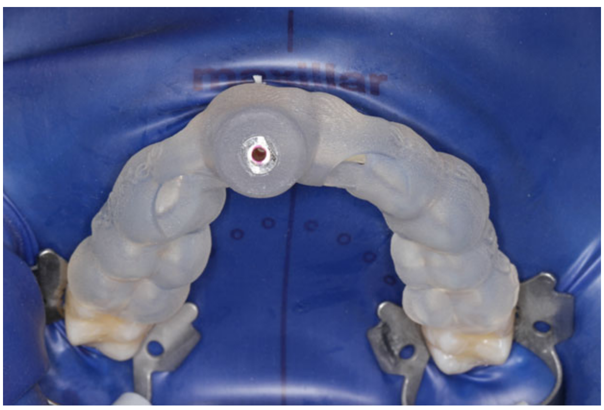

Fig. 8. Template positioned on the maxillary teeth to check its correct and reproducible fitting.

Fig. 9. View of the endodontic access cavity after root canal location.

fabricated by means of stereolithography (18). Both types need a radiographic template prior to CBCT acquisition. However, recent developments allow for matching a surface scan with CBCT data for virtual template creation and production by utilizing a 3D printer. Due to the high accuracy of printed templates and extended flexibility, this technology seems very promising (19).

Fig. 10. Control radiograph with silver cone in the root canal.

Fig. 11. Postoperative radiographic examination.

In dental traumatology and endodontology, guided procedures are new. A recent *in vitro* study performed by our work group revealed a predictable guided

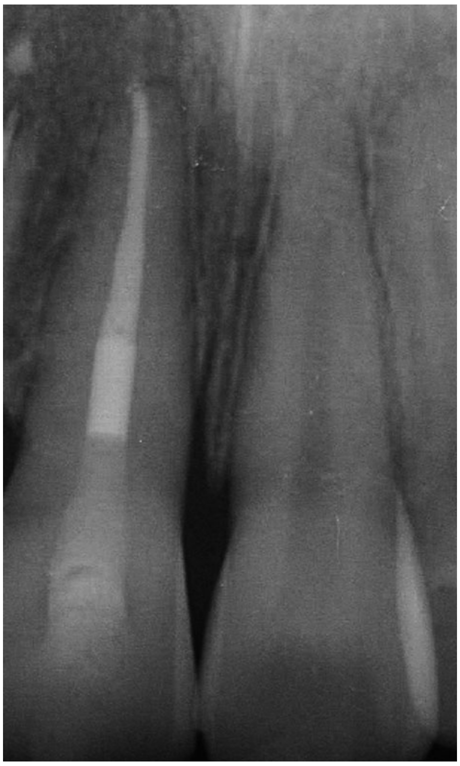

Fig. 12. Periapical radiograph after 15 months. No periapical radiolucency is visible.

location of root canals (20). With a mean deviation from the apical target point ranging from 0.17 to 0.47 mm for different aspects, the presented guided approach proved to have a sufficient accuracy to establish a safe treatment method for teeth with calcific metamorphosis and apical periodontitis. Thus, the presented technique might facilitate endodontic treatment of these difficult cases for skilled operators by providing the maximal conservation of coronal tooth structure, with a reduced risk of root perforation and a reduced chair time.

One limitation of the presented approach is that substance loss and modifications of the natural root canal geometry according to the dimension of the drill must be accepted. To enable a guided preparation, a straight-line access to the root canal is mandatory. In the present case, the access cavity had to be extended up to the incisal edge. The loss of hard tissue is comparable to a postspace preparation and may impair the stability of the root, thereby making the tooth more prone to fracture (21, 22). However, substance loss may be much greater if the root canal has to be located without guidance even when performed under the operating microscope. Furthermore, as shown with the present case report, it is not necessary to reach the virtually determined endpoint with the drill. Instead, root canal instruments can be used at certain depths to verify whether the root canal is accessible at that point to reduce further substance loss. In the present case, the root canal could be negotiated by a K-file size 10 already at 9 mm from the apex. Thus, the preparation with the special drill with a diameter of 1.5 mm could be stopped at that point and apical root canal preparation could be carried out using conventional rotary files. The final shape of the prepared root canal may not be considered as being too excessive in a central incisor of a young patient. With the further development and miniaturization of the preparation drill and the corresponding sleeve, it may be possible to reduce the substance loss and make the guided endodontic technique suitable for even delicate lower incisors.

Another potential drawback of the use of the drill for root canal location is initiation of dentinal cracks. It is well known that mechanical root canal preparation results in dentinal defects such as craze lines and cracks (23–25). Such defects are discussed as a cause for vertical root fracture, which usually leads to tooth loss (26). Further investigations are warranted to evaluate the risk for microcrack formation compared with conventional root canal instrumentation or postspace preparation. Conversely, due to the precise planning and location of the access cavity, teeth with PCC may benefit from an increased fracture resistance if more dentine is conserved as recently shown (27).

As an alternative to orthograde endodontic treatment, apicoectomy with placement of a retrograde filling may be considered in teeth with PCC and apical pathology. However, identification of the calcified root canal after root-end resection as well as cleaning of the infected part of the root canal may be challenging. Thus, the surgical treatment method is not regarded as the first option for these cases (10).

For the presented treatment approach, a CBCT is mandatory. Although new CBCT devices with a limited field of view can have a quite low radiation dose (28), it is still increased compared with conventional radiographs. However, without 3D imaging, a root canal treatment that requires multiple radiographs to determine the root canal location or even subsequent treatment for managing anterior tooth loss in adolescence can ultimately lead to a higher overall radiation dose.

Conclusions

The presented guided endodontics approach seems to be a safe, clinically feasible method for locating root canals and preventing root perforation in teeth with PCC that cannot be predictably accessed via traditional endodontic therapy. Aside from teeth with PCC, in the future, guided procedures in endodontics may help to easily and precisely access and treat specific areas in the root, which is hampered due to resorptions, perforations or fractured endodontic instruments.

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