Case Report

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Guided Endodontic Management of a Calcified Maxillary Central Incisor with Previous Iatrogenic Access using CBCT and Three-dimensional Printing: A Case Report

Dentistry Section

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ABSTRACT

Pulp canal obliteration presents a major clinical difficulty because the usual anatomical landmarks are lost, making conventional access preparation unpredictable and prone to iatrogenic errors. Recent advances in static guided endodontics, based on Cone-Beam Computed Tomography (CBCT) and digital planning, allow a more precise and conservative approach to canal localisation. A 24-year-old female patient presented with discolouration of the maxillary right central incisor with an unsuccessful attempt at root canal treatment. Clinical and radiographic findings revealed pulp canal obliteration along with an improperly directed access cavity and dentinal gouging, without any evidence of periapical disease. A CBCT-based guided endodontic workflow was adopted by merging CBCT data with a digital surface scan to design a virtual drill path and fabricate a Three-Dimensionally (3D) printed guide. The guide allowed controlled and accurate access to the residual canal while preserving surrounding dentin, after which conventional root canal treatment was completed. Intracoronal bleaching was then performed to improve the tooth shade. At the 6-month follow-up, the tooth remained asymptomatic and functional, with healthy periodontal and periapical status and a satisfactory aesthetic and functional outcome. Static guided endodontics provided a predictable conservative means of locating and treating a severely calcified canal in a tooth with a previously misdirected access. CBCT-based digital planning combined with three-dimensional printed guides allows precise and minimally invasive canal localisation in teeth affected by pulp canal obliteration. This digital workflow minimises the likelihood of procedural errors and excessive removal of dentin while ensuring safe and effective endodontic and aesthetic treatment.

Keywords: Computer-aided design, Cone beam computed tomography, Dental pulp calcification, Tooth bleaching

CASE REPORT

A 24-year-old female patient was referred for the management of the maxillary right central incisor (tooth 11) following an unsuccessful attempt at root canal treatment by a previous clinician one month earlier. The patient's chief concern was discolouration of the involved tooth for the past six months [Table/Fig-1a], with no history of pain, swelling, or discomfort, and the tooth was non-tender on percussion. The patient also reported a history of dental trauma to the anterior teeth during her childhood following a fall. Clinical examination revealed crown discolouration with an improperly directed access cavity and evidence of excessive dentinal removal suggestive of iatrogenic gouging [Table/Fig-1b], while the surrounding soft-tissues were within normal limits. Neural sensibility tests, electronic pulp test, and thermal test (cold test) were performed to diagnose the pulp condition. The electric pulp test yielded a negative result, and the subsequent cold test also showed no response.

An intraoral periapical radiograph demonstrated an inadequately prepared access cavity without canal instrumentation or obturation, with features suggestive of pulp canal obliteration (calcification) [Table/Fig-1c].

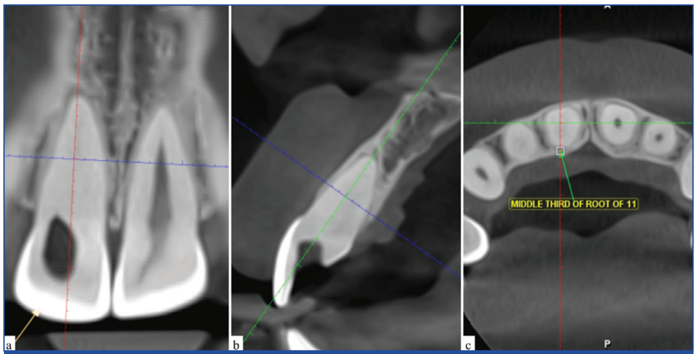
The CBCT was performed to assess the extent of dentinal damage and canal anatomy, and confirmed improper access preparation with significant dentinal gouging and failure to locate the root canal, with no associated periapical pathology [Table/Fig-2a-c].

Based on the American Association of Endodontists (AAE) diagnostic criteria, the pulpal diagnosis was previously initiated therapy and the apical diagnosis was normal apical tissues [1]. According to Grossman, the clinical findings in the present case are diagnostic of calcific degeneration of the pulp, characterised by crown discolouration, negative response to pulp sensibility tests, and radiographic obliteration of the pulp space [2].

[Table/Fig-1]: a) Preoperative clinical photograph showing discolouration of the maxillary right central incisor; b) Clinical photograph revealing an improperly directed access cavity with evidence of iatrogenic dentinal gouging; c) Preoperative intraoral periapical radiograph demonstrating an inadequately prepared access cavity without canal instrumentation or obturation, with features suggestive of pulp canal obliteration (calcification) and a subtle radiolucent outline suggestive of residual canal space (arrow).

Although the tooth was asymptomatic, the history of prior access preparation raised concerns regarding pulpal contamination and long-term pulpal viability; therefore, following the informed consent of the patient, definitive root canal treatment followed by non-vital bleaching was planned to achieve a predictable biological outcome and prevent future pulpal complications.

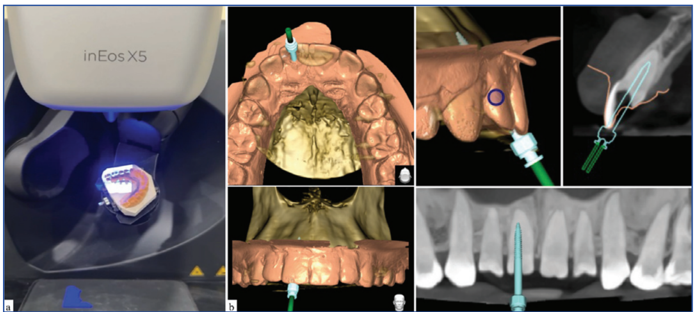
Diagnostic casts were fabricated for extraoral digital surface scanning (Sirona inEos X5) [Table/Fig-3a]. RealGUIDE software



[Table/Fig-2]: a) Sagittal CBCT section of tooth 11 demonstrating improper access preparation with significant dentinal gouging and failure to locate the root canal; b) Coronal CBCT section confirming canal obliteration (absence of associated periapical pathology) c) Axial CBCT section canal obliteration.

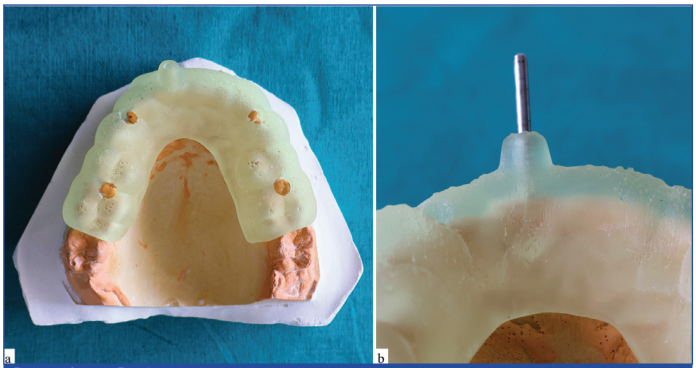
(Universal Open System) was used for merging the CBCT and digital surface scan data. The CBCT data were used to coordinate a virtual drill to calculate the sleeve's location. Utilising digital data, the virtual instrument was configured to be 28 mm long and 1.5 mm in diameter and tailored to accommodate suitable cutting instruments. Canal localisation was challenging due to advanced calcification. A subtle radiolucent outline may be suggestive of residual canal space on the intraoral periapical radiograph [Table/Fig-1c]; however, the canal was not clearly identifiable on CBCT. This discrepancy may be attributed to the higher contrast resolution of two-dimensional radiographs in detecting faint linear radiolucencies, whereas CBCT visualisation may be limited by voxel size, beam hardening, and advanced calcification.

In such scenarios, access planning was guided by the law of canal centrality and the anatomical position of the root canal relative to the external root morphology. A virtual drill path was designed using RealGUIDE software (Universal Open System) from the coronal entry point to a predefined target point, which was determined based on the anticipated location of the canal within the root, guided by external root morphology, adjacent teeth, and alignment along the long axis of the tooth [Table/Fig-3b].



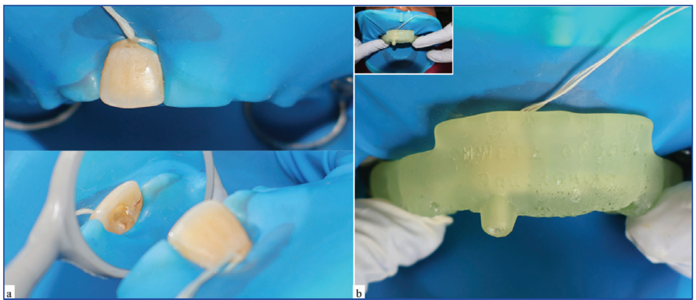
[Table/Fig-3]: a) Diagnostic cast fabricated for extraoral digital surface scanning; b) Virtual planning image illustrating the proposed drill path aligned along the long axis of the root for guided access preparation.

This planning allowed fabrication of a 3D-printed guide to direct the bur along the predetermined access path [Table/Fig-4a]. The 3D-printed guide was fabricated using a Fused Deposition Modeling (FDM) 3D printer using a thermoplastic filament material (PLA). Printing was performed with a layer thickness of 100 μm using standard manufacturer-recommended parameters. Post-processing included removal of support structures and surface finishing. A sleeve was intended in the stent's design, which acts as a channel that constrains the bur to follow the planned virtual drill path, which prevents deviation, tilt, or over-penetration during access preparation and ensures repeatable and controlled depth of drilling [Table/Fig-4b]. Prior to clinical use, the guide was sterilised using ethylene oxide gas in a Central Sterile Services Department (CSSD), a low-temperature sterilisation method suitable for thermoplastic materials, and subsequently sealed in a sterile pouch to ensure aseptic conditions during the procedure.



[Table/Fig-4]: a) Three-dimensionally printed tooth-supported endodontic guide positioned on the dental cast to verify fit and adaptation based on the virtual treatment plan; b) Close-up view of the guide showing the incorporated sleeve designed to control bur angulation, depth, and trajectory during guided access preparation.

The guide fit was initially verified on the dental cast to ensure accurate adaptation [Table/Fig-5a]. Subsequently, it was positioned intraorally, and its fit was confirmed by ensuring complete seating and stable adaptation on the dental arch without any rocking or displacement. Guide stability was further maintained through controlled manual pressure during verification [Table/Fig-5b].



[Table/Fig-5]: a) Rubber dam isolation with tooth 11; b) Intraoral positioning of the tooth-supported endodontic guide over the rubber dam, showing stable seating of the guide with manual stabilisation by using gentle pressure.

Lignocaine 2% with 1:80,000 adrenaline (Xylocaine 2% injection, Zydus Cadila, India) was administered to ensure patient comfort during the procedure and to manage any potential discomfort arising from possible residual pulpal tissue. Rubber dam isolation was achieved with tooth 11 [Table/Fig-5a]. Following isolation, the stent was positioned over the rubber dam, covering the maxillary arch from teeth 16 to 26 and including the involved tooth (11) [Table/Fig-5b].

A round bur (Round LN bur, Mani, Japan) with a length of 28 mm and a diameter of 1.5 mm was inserted into the stent to begin the access opening. During guided access preparation, sleeve retention was ensured by continuous engagement of the bur within the guide sleeve, facilitating controlled and stable drilling along the planned trajectory. Radiographic verification was performed following guided access preparation, confirming accurate bur trajectory and central positioning of the access path within the root, consistent with the planned virtual drill path [Table/Fig-6a]. Intraoral periapical radiographs were obtained at 2 mm intervals to verify the orientation of the preparation. The canal was located and successfully traversed

[Table/Fig-6]: a) Intraoral periapical radiograph confirming accurate bur trajectory following guided access preparation; b) Working length determination radiograph; c) Master cone fit radiograph; d) Post-obturation radiograph showing root canal filling and post-endodontic composite restoration.

in the middle third of the tooth. Canal patency was achieved using a size 10 D-Finder file (MANI, Japan), following which the working length was established at 19 mm using an electronic apex locator and subsequently confirmed with an intraoral periapical radiograph [Table/Fig-6b]. A reproducible glide path was then established using a size 15 C+ file (Dentsply Sirona). Biomechanical preparation was performed using the crown-down technique with ProTaper Next rotary instruments (Dentsply Sirona) in the sequence X1 (17/04) followed by X2 (25/06), with irrigation using 3% sodium hypochlorite and 17% Ethylene Diamine Tetra Acetic Acid (EDTA) (RC Help). After preparation up to X2, the master cone fit was verified [Table/Fig-6c]. Obturation was performed using warm vertical compaction with a bioceramic sealer (Bio-C Sealer, Angelus, Brazil). An intraoral periapical radiograph confirmed that the access remained centered along the long axis of the root without lateral deviation. Clinically, the access cavity and canal orifice were aligned with the expected anatomical position and centered within the dentinal walls, thereby indirectly validating the application of the law of canal centrality. The access cavity and incisal edge were then restored with composite resin (Spectrum, Dentsply Sirona) to re-establish form and aesthetics [Table/Fig-6d].

After one week, intracoronal bleaching was performed by creating an access through the composite restoration into the pulp chamber. A paste of 35% hydrogen peroxide mixed with sodium perborate was placed and temporarily sealed. A single bleaching session produced a satisfactory improvement in tooth shade. Following the bleaching procedure, a noticeable and clinically acceptable improvement in tooth shade was achieved [Table/Fig-7a,b].

[Table/Fig-7]: a) Pre-bleaching clinical photograph obtained after completion of root canal treatment; b) Post-bleaching clinical photograph demonstrating a satisfactory improvement in tooth shade following intracoronal bleaching.

At the 6-month follow-up, the tooth presented as functional and asymptomatic, with normal periodontal probing and no discolouration. Periapical radiographic evaluation showed an intact periodontal ligament space with no evidence of periapical pathology [Table/Fig-8].

DISCUSSION

In dental practice, tertiary dentin deposition which is also referred to as pulpal canal calcification or sclerosis is frequently observed. Tertiary dentin is classified as reactionary or reparative dentin based on the type of pulpal response. Following traumatic or iatrogenic insults (such as auto transplantation, extensive orthodontic treatments, iatrogenic dental procedures, jaw fractures, orthognathic surgery, and other disorders), accelerated tertiary dentin deposition may lead to progressive narrowing or obliteration of the pulp canal [3]. The word “calcific metamorphosis” is described as “a pulpal response to trauma characterised by rapid deposition of hard tissue within the canal space” in the Glossary of Endodontic Terms [1]. Nevertheless, due to its more precise representation of the phenomenon, “pulp canal obliteration,” as proposed by Andreasen FM et al., appears to be a more suitable term for describing the outcomes of dental trauma [4].

[Table/Fig-8]: Periapical radiograph obtained at the 6-month follow-up.

Clinical studies have reported a wide variation in the incidence of pulp canal obliteration following traumatic dental injuries, ranging from 3.7% to 40% [3]. Pulp canal obliterations can be partial or complete, but they are not pathogenic in and of themselves. According to studies published in the literature, patients with pulp canal obliteration may eventually develop pathological changes like pulp necrosis, apical periodontitis (1%-27.5%), and yellow discolouration (8.3%-79%) [3]. Obliterated teeth require extended monitoring due to potential delayed pulp necrosis or periapical pathosis, with literature recommending annual clinical/radiographic examinations for 5+ years [3,4]. Based on the assumption that clinical symptoms are likely to appear gradually, literature supports early intervention in pulp canal obliteration. As a result, root canal therapy has been suggested prior to the complete obliteration of all anatomic landmarks [5].

Obliterated canals are treated with a variety of instruments, including orifice openers, ultrasonic tips, and Long Neck (LN) Mueller burs typically under magnification [6]. These are additions to the traditional armamentarium for locating and overcoming destroyed channels, but they may need a lot more time and effort than in typical situations. Ultrasonic tips offer a conventional alternative for calcified canal negotiation, using magnification to remove obstructions conservatively and reduce iatrogenic risks. Calcium hydroxide ($Ca(OH)_2$) troughing involves placing paste to soften calcifications over time, aiding access after 1-2 weeks, often combined with NaOCl irrigation [6]. However, these approaches are more suitable for less complex cases and lack the precision and predictability offered by guided endodontics in teeth with advanced calcification and prior iatrogenic access. Despite these adjuncts, canal negotiation remains technically demanding due to loss of anatomical landmarks, even under magnification, as emphasised by the American Association of Endodontists [7,8]. Furthermore, such procedures may result in excessive dentin removal and an increased risk of iatrogenic perforation, potentially compromising long-term tooth survival [8].

Krastl G et al., introduced the concept of guided endodontics and demonstrated its clinical application in an in vivo case report [7]. A computerised technique for identifying obstructed canals was presented using digital scans of the tooth surface and CBCT images. Using the same data acquisition and 3D printing technology, a sleeve-guided template was designed and fabricated to facilitate access and aid in canal localisation. This approach has been shown to provide accurate transfer of digital planning to the clinical procedure, allowing predictable and controlled access preparation [7].

Subsequently, Connert T et al., demonstrated its clinical application in a maxillary central incisor with an obliterated canal using guided endodontic therapy. They came to the conclusion that the comparatively low angle deviation (1.59°-1.8°) and negligible 3D deviation at the bur tip (0.12-0.47 mm) contributed to the high success rate [9]. Consistent with these findings, a study by Bansal RK et al., demonstrated that guided endodontic access results in significantly less tooth structure loss and lower angle deviation than conventional access in calcified canals [10]. Multiple studies have demonstrated the effectiveness of guided endodontics in the management of pulp canal obliteration in anterior teeth with significantly higher accuracy compared to freehand approach (e.g., 96.6% vs 83.3%) [11], supporting the approach used in the present case.

In addition to experimental and comparative studies, several recent case reports have demonstrated successful guided endodontic management of calcified maxillary central incisors using CBCT-based digital planning and 3D-printed guides. Nabavi S et al., (2025) treated a trauma-induced calcified maxillary central incisor using a static CBCT-integrated guide and reported precise canal negotiation with minimal dentin removal, with complete periapical healing at 18 months [12]. Panithini D et al., (2023) described dynamic navigation-assisted guided endodontics using the Navident system for management of calcific metamorphosis in a maxillary central incisor, achieving successful canal negotiation in a single visit with radiographic healing [11]. Zargar N and Amiri M reported static guided endodontic access in a trauma-related calcified and discoloured maxillary central incisor using a palatal 3D template, with complete apical healing at 18 months [13]. Comparable outcomes have also been reported by Hegde S et al., [5]. These reports collectively reinforce the predictability, conservative dentin removal, and favourable healing outcomes associated with guided endodontics in anterior teeth with pulp canal obliteration, findings that are consistent with the present case particularly in terms of controlled access and preservation of surrounding dentin.

The presence of significant canal obliteration, along with a pre-existing iatrogenic access cavity (dentinal gouging), posed additional challenges in canal localisation and increased the risk of further deviation during access preparation. To overcome these challenges and ensure precise canal negotiation while preventing additional structural damage, guided endodontic therapy was employed. The existing iatrogenic cavity was incorporated into the guided access design and refined along the planned drill path. This approach enabled controlled access along a predefined drill path, facilitating canal negotiation and correction of the previous deviation while minimising additional dentin removal and preserving structural integrity.

Connert T et al., explained how a stent was designed to fit incisally and provide straight-line access in a case study involving mandibular central incisors [14]. Although a tooth-supported guide was used in the present case, the incisal edge was also involved in the guide design to facilitate straight-line access to the obliterated canal.

Guided endodontics risks include perforation in cervical calcifications due to the dense resistance of dentin, especially when using improper bur selection or sleeves [7]. The procedures have a number of drawbacks despite their advantages like: imprecision in curved canals, CBCT artifacts from metals, contraindication in limited mouth opening, and high costs limiting accessibility [7,11]. Workflow complexity demands software expertise, and its less effective for narrow canals invisible on scans [7]. These must be weighed against benefits in complex cases like this [11]. AAE guidelines emphasise periodic recalls to assess vitality, seal integrity, and periapical healing [1]. In the present case, a 6-month follow-up demonstrated an asymptomatic and functional tooth with satisfactory periapical status. Further periodic recalls at 12 months and annually thereafter have been advised in accordance with these recommendations.

Straight root canals or straight sections of curved canals can be treated endodontically with a guided approach. Although guided endodontic procedure requires digital planning and guide fabrication, multiple studies have shown that guided access preparation results in significantly lower deviation, reduces iatrogenic errors, and shorter chairside time compared with conventional techniques, thereby making it a more predictable and efficient approach for the management of calcified canals [15]. The need for digital planning and guide fabrication may increase treatment cost. However, considering the decreased chairside time and iatrogenic risks, the cost might not have been too high in perspective. Even in situations when guided endodontic therapy is not planned, access cavities should follow the 'as small as practical' principle to preserve pericervical dentin and reduce fracture risk [16].

When managing discoloured non-vital anterior teeth, treatment options include bleaching, laminate veneers, and full coverage crowns; however, crown and veneer restorations require irreversible removal of sound tooth structure and are therefore invasive. Although laminate veneers represent a less destructive alternative compared with crowns and are capable of masking discolouration, they still require tooth preparation and may be associated with fracture, debonding, and marginal leakage. In contrast, non-vital bleaching provides a conservative, rapid, and economical approach for improving tooth colour without compromising remaining tooth structure [17].

A direct comparison between the planned and actual drill trajectory using CBCT superimposition was not performed. Additional postoperative CBCT imaging was avoided to minimise radiation exposure, which may be considered a limitation of the present case. However, clinical and radiographic evaluation demonstrated that the guided access was centered along the long axis of the root without any evidence of deviation or perforation, with preservation of surrounding dentin. These findings suggest clinically acceptable accuracy of the guided approach. Further studies incorporating CBCT-based quantitative assessment of accuracy and deviation are warranted.

CONCLUSION(S)

Pulp canal obliteration significantly increases the risk of iatrogenic errors during conventional access preparation. This case demonstrates that CBCT-based static guided endodontics enables accurate and conservative canal localisation even in teeth with severe calcification and previously misdirected access cavities. By minimising unnecessary dentin removal and procedural deviations, guided endodontics improves treatment safety and predictability. The ability to combine guided access with conservative intracoronal bleaching further enhances both functional and aesthetic outcomes in anterior teeth.

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