Case Report

Enhanced Precision in Endodontic Treatment of Calcified Canals through Static Navigation: Case-based Perspective

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ABSTRACT

In modern endodontics, calcified root canals pose a diagnostic and therapeutic challenge. Their complex and often obliterated anatomy often leads to problems in canal location, iatrogenic errors such as perforations, and missed canals. Case 1 illustrates the traditional method, requiring greater dentin removal, cautious access modification, and ultrasonic assistance to finally negotiate the calcified canal. Case 2 demonstrates the successful application of Static navigation (SN) in treating a pulp canal-obliterated maxillary central incisor with periapical pathology in a young adult. SN with cone-beam computed tomography (CBCT) data and 3D-printed surgical guides has become a revolutionary method for treating such issues with the highest accuracy and minimal invasive access. Based on digital planning and CBCT integration, a 3D-printed endodontic guide was fabricated, enabling guided access to the calcified canal with minimal compromise to surrounding tissue. Clinical and radiographic images reveal (i) exact positioning of the 3D guide, (ii) canal negotiation, (iii) biomechanical preparation, and (iv) 3D obturation. Hitherto, the literature has supported an increasing reliance on guided endodontics for cases of pulp canal calcification, and studies have shown improved outcomes with reduced operative risk. This case demonstrates the importance of a precision-guided, minimally invasive approach and highlights that static navigation, which can be reviewed preoperatively, can significantly improve treatment outcomes in situations traditionally considered high-risk or impossible to treat with conventional methods. Ultimately, interdisciplinary collaboration and technological innovation are vital to extending the benefits of this technique in both clinical and academic settings.

Key words: Access cavity, computer-aided, cone beam computed tomography, guided endodontics, minimally invasive access, printed templates, pulp canal obliteration

Calcified root canals, often following pulp canal obliteration (PCO), can pose a challenge for endodontics because they are difficult to identify and negotiate without injuring the surrounding dentin. PCO can come to light following dental traumatic incidents, ageing, orthodontic treatment, and extensive restorations. The tertiary dentin is laid together with lateral narrowing or obliteration. This condition is considered to have an incidence rate of 4-24% in anterior maxillary teeth [1]. Due to unsatisfactory canal visibility, conventional treatment protocols, such as regular canal enlargement to reach the natural orifice of a canal, may be detrimental. Observation of the canal can result in perforation or excessive removal of dentin. Unlike periapical radiographs, which lack resolution, CBCT offers high resolution and triple orientation, allowing for the precise visualization of canal patency, root morphology, and periapical pathology [2]. Nonetheless, precisely channelizing the CBCT data to clinical action was problematic, and thus digital workflows and guided endodontic technologies were adopted. Static computer-aided navigation utilizes CBCT data and intraoral scanning to establish a virtual treatment plan and 3D-print a surgical guide; this guide provides safe, millimetric precision in access cavity preparation, comparable to that in implantology. SN has proven highly successful in finding canals in PCO cases, achieving a 100% success rate in anterior teeth compared to lower success rates with freehand techniques. The use of SN also reduces operative time, decreases errors, and helps conserve the peri-cervical dentine necessary for tooth longevity [3, 4].

The technology enhances predictability and control over entry angle and depth, while also reducing complications such as root perforations. It can also be employed to treat pulp stones, iatrogenic blockages, or anatomical anomalies such as dens invaginatus [5]. Unfortunately, the limiting factor remains the requirement of an advanced imaging and planning software; the availability of a 3D-printing facility for the guide generation, and the stability of the guide throughout the

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procedure period will be of paramount importance, as slight movement of the guide in the functioning will undermine the accuracy of the whole process [6]. Overall, it can be said that SN represents a paradigm shift in manual versus computer-assisted endodontics, offering less invasive treatment procedures with better control over canal calcifications and greater safety and predictability. This trend is expected to be further enhanced with advancements in digital dentistry [7].

1. CHALLENGES IN CONVENTIONAL MANAGEMENT OF CALCIFIED CANALS:

Conventional endodontics may be challenged by the difficulty to visualize canal space, especially at the middle and apical third of the canal. This may lead to excessive dentin removal, perforations, missed canals, and subsequent treatment failure. Surgical microscopes, ultrasonic tips, and modified access strategies can all increase the prognosis, yet the success still lies on the hands of the operator and remains an uncertain factor [8]. Despite technological advancements, the traditional freehand method still suffers from limited precision, often putting the patient at unnecessary risk.

2. DIGITAL NAVIGATION IN ENDODONTICS: AN OVERVIEW

First created for implantology, SN, with their initial use and application, have, in recent years, come to confront the issues raised by PCO. SN employs cone-beam computed tomography (CBCT) and digital intraoral scanning to virtually plan the access path. This information is then fed to a 3D printer, which designs and prints a guide that is crucial for instructing the bur to precisely locate the calcified canal [9]. The concept is similar to guided implant surgery and promotes the same level of precision and minimally invasive approach.

3. ACCURACY AND EFFICACY OF STATIC NAVIGATION IN ENDODONTICS:

Indeed, a multitude of pre-clinical and clinical studies have provided strong support for using SN methods when calcified canals are located and accessed with high accuracy. For example, a success rate of 96% in canal location using SN, compared with only 74% with conventional methods. Using guided access was 2 to 3 times more accurate than traditional access, effectively reducing the risk of perforation to a minimum [10]. Moreover, SN-based methods can preserve 42-64 percent more pericervical dentin than freehand methods.

4. CLINICAL APPLICATIONS AND SUCCESS IN CALCIFIED CANAL CASES:

In Buchgreitz et al.'s 2020 study, a retrospective design encompassing multiple institutions revealed that static guides achieved a high success rate in treating anterior teeth with pulp canal obliteration. The canal was negotiated completely in 94% of the 50 studied cases, and there were no intraoperative complications [10]. In a recent case series, Alberdi et al. demonstrated that static-guided access can be effectively used to locate and treat calcified root canals across different tooth types, with high clinical success and no reported iatrogenic complications [11]. The results suggested that SN could aid canal detection and enhance long-term clinical outcomes.

CASE REPORT

Case 1- Traditional Approach

A 27-year-old patient reported to the department with the chief complaint of pain in the upper front tooth region. The history revealed that root canal treatment had been initiated by a previous dentist for tooth 12. The treatment was unsuccessful as the canal was calcified and could not be negotiated.

In an attempt to locate the canal, excessive dentin was removed, further complicating the case. On examination, the tooth was tender with a partially prepared access cavity (Figure 1A). During our intervention, the major challenge was negotiating the heavily calcified canal, which required careful refinement of the access cavity and additional dentin removal. We initiated treatment and, with the aid of an ultrasonic tip and a hand C-pilot file (#08), successfully navigated the calcified canal (Figure 1B). This allowed us to proceed with conventional cleaning, shaping, and subsequent management of the tooth.

FIG 1: Case 1 - A: Pre-op radiograph, attempted Access; B: canal negotiated with No.8 C-pilot file

Case 2- Guided Endodontics

A 25-year-old male presented with pain and swelling in the maxillary anterior region, specifically the upper right central incisor. There was no history of trauma or endodontic treatment given to him. On examination, the tooth was discolored, there were negative vitality test results, asymmetric gingival zenith, tenderness to palpation/percussion, and radiographic evidence of a periapical radiolucent area with PCO.

Diagnosis: On account of clinical signs, radiographic interpretation, and pulp sensibility testing, a diagnosis of chronic apical periodontitis secondary to pulp necrosis with PCO in relation to the maxillary left central incisor was made.

Static Navigation-Assisted Endodontic Protocol: The exact drill path was computed digitally by planning using both CBCT and intraoral scans to access the calcified canal. A custom-fabricated 3D-printed surgical guide with a metal sleeve was produced, ensuring that the angle at which the burr was held, and the depth control were done to specifications. A canal that opened under the guided access was negotiated using a #10 K-file safely, followed by cleaning and shaping, calcium hydroxide dressing, and warm vertical compaction obturation.

Step-by-Step Workflow

1. Digital Imaging and Data Acquisition- For canal trajectory and periapical pathology, the use of a CBCT is suggested, while for tooth morphology and occlusion, the need is for an intraoral scan. (Figure 2)

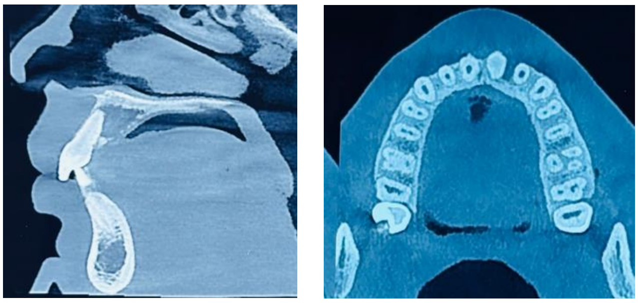

FIG 2: Case 2- Digital Imaging of a Cone Beam CT scan

2. Virtual Planning- For merging DICOM and STL files, software (Acteon imaging software) is required for planning the design of an almost 11.5-mm-deep drill path. (Figure 3)

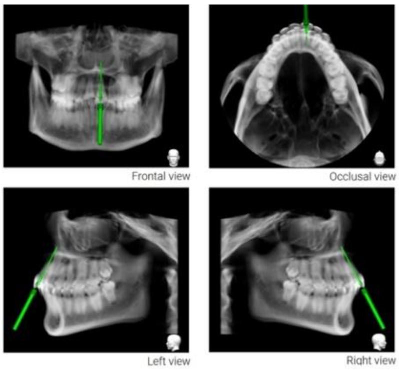

FIG 3: Virtual Planning: The CBCT

3. Guide Fabrication- Once procured, it is 3D-printed using surgical resin with integrated metal sleeves for precision. (Figure 4)

FIG 4: 3D-printed Guide with integrated metal sleeves for precision.

4. Clinical Application-Intraoral testing for fit, rubber dam isolation, and guided bur access. (Figure 5)

FIG 5: Intraoral testing for fit, rubber dam isolation, and guided bur access.

5. This stage includes locating and negotiating the canals, guided entry, and determination of the working length, followed by cleaning and shaping of the root canals with the use of rotary instruments. This is then followed by irrigation, calcium hydroxide medication, and obturation at the very end. (Figure 6)

FIG 6: A: canal negotiated with No.8 K file; B: obturation done

DISCUSSION

The cases highlight the importance of integrating digital endodontics with guided access for managing teeth with calcified canals, which often develop after trauma, ageing, or developmental anomalies. Pulp canal obliteration poses an inherent challenge in these cases because the canal lumen is either significantly reduced or completely obliterated. Any attempt at instrumentation may introduce errors, cause excessive dentin removal, or lead to perforations that could create problems in anterior teeth, where esthetics are a primary concern. The static navigation system facilitated precise canal entry through minimally invasive preparation, preserving tooth structure and thereby maintaining the long-term integrity of the root. In contrast, freehand access relies on the operator's experience and tactile sense; SN, on the other hand, provides pre-planned accuracy, reduces chairside time, and mitigates significant risk.

Both static and dynamic navigation methods offer better accuracy than traditional methods; the former is more commonly used because it is cheaper to set up, simpler to use, and more readily commercially available. Real-time and versatile though they might be, dynamic navigation systems require extensive operator training and very expensive equipment. Pellegrino and co-workers, together with recent reviews on guided endodontics, suggest that static navigation is better adapted to straightforward single-canal anterior teeth with obliteration, whereas dynamic navigation is more suitable for multi-rooted teeth or situations requiring real-time trajectory adjustments [12].

The aim of using advanced digital planning tools to merge CBCT and intraoral scan data was to preserve anatomical alignment, while the 3D-printed guide minimized intraoperative uncertainty. A CBCT scan integrated with CAD/CAM design and 3D printing forms the core of SN, with voxel sizes as small as 75 microns, allowing high-resolution visualization of even partially obliterated canals. When this volumetric information is combined with STL files from intraoral scans, a precise drill path can be planned, resulting in a more predictable procedure, reduced chairside time, and improved patient experience [13]. The design of the guide (Figure 2-4) was carefully thought out, including soft-tissue clearance and inter-arch considerations to allow uncompromised access and proper burr angulation. The postoperative course was uneventful, with resolution of clinical symptoms and radiographic evidence of periapical healing throughout follow-up.

Although there are encouraging results, the literature on SN in endodontics is limited by small sample sizes and short follow-up durations. With many of them being case reports or in vitro simulations. Most of the data focuses on anterior teeth, while few studies address posterior teeth or multi-root systems due to the difficulties involved in designing guides. Additionally, the requirement for a wide-mouth opening and a clear surgical field limits its use in patients with limited access [14].

FUTURE PROSPECTIVES

Future prospective of static navigation in endodontic treatment of calcified canals. The integration of SN into endodontics heralds truly transformative times for precision-based dental care. Although the product is still finding its market, one can forecast significant advances in clinical practice, digital workflows, artificial intelligence, and broadly applicable disciplines.

1. Integration of Artificial Intelligence (AI) and Machine Learning (ML)

In the future, the workflow will utilize Artificial Intelligence and Machine Learning to identify calcified canals on CBCT scans, perform automatic segmentation, predict canal anatomy and treatment, and ultimately design customized surgical guides for each patient based on their anatomical characteristics and grades of calcification.

2. Evolution of 3D Printing and Chairside Guide Fabrication

High-speed biocompatible chairside 3D printing advances will open the doors for guide fabrication on the same day, using portable scanning systems and integrated CAD/CAM systems, making SN viable for emergency treatments.

3. Fusion with Dynamic Navigation and Mixed Reality

Hybrid arrangements will merge SN precision with the free navigation feature, while AR/VR will overlay the virtual drill paths right onto the clinician's viewpoint, thereby getting rid of those physical templates.

4. Minimally Invasive Endodontics and Conservation-Driven Dentistry

In the future, ultraconservative access will be supported by the use of micro-guided burs and high-precision templates via SN tools, preserving pericervical dentin in accordance with biomimetic dentistry principles.

5. Educational Revolution and Training Integration

The dental training will integrate VR-based simulators, 3D-printed practice models, and digital skill assessment systems to prepare clinicians for guided endodontics in real practice.

6. Interdisciplinary Applications and Expanded Clinical Indications

In this manner, SN shall wield its influence beyond endodontics into implantology, periodontology, pediatric endodontics, and the management of complex anomalies, enabling other specialities to gain access and precisely treat patients.

7. Regulatory Standardisation and Cost Reduction

The costs for calcified canal treatments will be low due to mass production, custom design on cloud-based platforms, and insurance acceptance of SNs, which will standardise SNs for widespread use.

8. Real-Time Outcome Tracking and Predictive Analytics

When integrated with a digital record system, continuous outcome monitoring, AI-driven feedback loops, and predictive analytics can make treatment planning and prognosis dynamic over time.

CONCLUSION

For many years, the treatment of calcified root canals has been one of the most challenging clinical endodontic scenarios. Usually affected by trauma or ageing, PCO causes the almost total obliteration of the canal space on radiographic examination. The anatomical complexities place a clinician at significant risk of errors, such as excessive dentin removal, improperly locating the canal, or root perforation —all of which could jeopardize the prognosis of the tooth and its ultimate survivability, as seen in Case 1. The primary objective of static computer-aided navigation (SN) is to enhance endodontics by achieving a level of precision comparable to evidence-based, minimally invasive, and highly accurate methods for locating and navigating calcified canals.

The second case exemplifies the clinical utility of SN technology in real-world scenarios involving young adults, particularly when working with a calcified maxillary central incisor, a tooth that is both esthetically and functionally critical. By integrating cone-beam computed tomography with intraoral surface scanning via a digital workflow, the SN approach provided a customised 3D-printed surgical guide for each patient's anatomy. This technology offers micron-level access to the canal, conserving as much pericervical dentin and natural tooth structure as possible, from a surgical perspective, thereby resulting in significantly less risk than freehand access.

The visual data and clinical images demonstrate the efficacy of this guided access, which enabled canal debridement, disinfection, and obturation, along with radiographic and clinical follow-up signs of healing. They form an additional evidence base supporting SN as a predictable, safe, and conservative approach to treating complex root canals. However, with clinical success evident for SN, one must weigh its limitations against this consideration. These limits include cost, dependence on technology, and the time required for planning.

Such barriers, however, are projected to decrease as more people use it, 3D printing procedures evolve, and planning software becomes open source. The broader implication of SN-guided endodontics lies in the shifting paradigm of modern dentistry, from traditional, tactile, experience-based navigation to digital, precision-driven workflows. Such transformation increases not only treatment predictability but also enhances patient safety and comfort. SN gains special importance in anterior esthetic zones, where mislocation of a canal or loss of tooth structure may have dire cosmetic and functional repercussions.

Static navigation offers a groundbreaking clinical management solution for calcified canals. In this respect, it also illustrates the direction modern endodontics is taking- one that is digitally guided, biologically conservative, and interdisciplinary. Continued research, clinical validation, and innovation in software integration, guide manufacturing, and chairside planning tools will further enhance the portability and usefulness of this technique.

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