ISSN: 2581 – 3633
PubMed - National Library of Medicine - ID: 101745081

International Journal of Medical Science and Advanced Clinical Research (IJMACR)

Available Online at:www.ijmacr.com

Volume – 8, Issue – 3, June - 2025, Page No.: 125 – 130

Guided Endodontics: Clinical Solution for the Challenges of Calcified Canal

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How to citation this article: Dr. Imit Pal Saluja, Dr. Renu Singh, Dr. Akshata Ohm, Dr. Mohammed Abdul Samee, Dr. Lavleena Harchandani, Dr. Sahil Vashisht, "Guided Endodontics: Clinical Solution for the Challenges of Calcified Canal", IJMACR- June - 2025, Volume – 8, Issue - 3, P. No. 125 – 130.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Guided endodontics—a technique combining CBCT imaging, digital planning, and 3D-printed/static or dynamic guides—is revolutionizing the management of calcified root canals. Compared to conventional free-hand methods, it improves precision, conserves tooth structure, reduces operative time, and lowers risk of iatrogenic errors. Studies report ≥95% success in locating obliterated canals with minimal accidents. However, factors such as apical calcification, prior treatments, and lower-arch positioning may affect accuracy. Limitations include equipment costs, learning curves, limited mouth opening, or scanner incompatibilities. As evidence grows, guided endodontics is becoming a reliable, operator-independent approach to complex canal cases.

Keywords: Guided endodontics; calcified canal; pulp canal obliteration; CBCT; 3D-printed guide; dynamic navigation; canal negotiation.

Introduction

- **Pulp Canal Obliteration (PCO)**—due to trauma, aging, caries, orthodontics, etc.—leads to partial or total canal calcification and complicates access, shaping, and disinfection[1].
- Conventional access risks excessive dentin removal, perforation, iatrogenic errors, and fractures.

- **Guided endodontics** leverages pre-operative CBCT to plan a precise drill path and employs static (3D-printed guides) or dynamic (real-time navigation) systems to overcome these challenges[2].
- Its adoption has increased since initial reports circa 2019, with expanding clinical and ex vivo research[3].

2. Techniques & Clinical Workflow[4-6]

1. **CBCT imaging** provides 3D visualization of canal anatomy, obliteration extent, and pathology
2. **Digital planning** overlays CBCT and intra-oral scans to design the optimal access path and select bur diameter (typically 0.75–0.9 mm).
3. **Guide fabrication**
   - *Static guides* are 3D-printed templates that physically constrain the bur
   - *Dynamic navigation* systems track the bur in real-time, allowing flexibility and adjustment during drilling
4. **Drilling and canal negotiation**: Pathway follows the guide to reach patent canal efficiently and conservatively

3. Evidence & Clinical Outcomes

3.1 Accuracy and Success Rate[7,8]

- In a systematic review of 45 diverse studies (ex vivo, case reports, series), 43 (96%) reported successful canal localization with guided access; only two reported failures
- Umbrella review data (2024) confirmed superior precision over conventional techniques across microsurgery and canal access
- Dynamic guided approaches exhibited > 95% accuracy in both in vitro and clinical setups.

3.2 Conservation & Efficiency[9,10]

- Guided access preserves more dentin, prevents excessive substance loss, and limits canal deviation in contrast to free-hand methods.
- Operative time is significantly reduced—even non-specialist operators using dynamic guidance achieved faster and satisfactory access compared to specialists using conventional methods

3.3 Independent of Operator Experience[11]

- A scoping review (Aug 2024) concluded that experienced and novice clinicians performed similarly when using guided navigation
- Additional reports note reproducible outcomes regardless of experience level

3.4 Factors Influencing Precision[12]

- Observational clinical data highlight that apical calcification increases the odds of off-center drilling (approx. 15×), and prior treatment or lower-arch location may further contribute
- No perforations were reported across evaluated guided cases, but caution is advised in complex dental morphologies.

Discussion[13-14]

Advantages

- **High precision & minimal invasiveness** reduce unnecessary dentin removal and structural weakening
- **Reproducibility across clinicians**, including non-specialists, supports broader clinical implementation
- **Faster procedure times** enhance patient comfort and clinic efficiency
- **Low complication rates**, particularly zero perforations in literature series

Limitations & Challenges[15-16]

- **Apical obliteration** requires careful planning or may necessitate fallback strategies.

- **Operatory constraints**: Small mouths, limited interocclusal space, or aligners can hinder guide placement.
- **Resource demands** include CBCT access, digital planning software, 3D printers, and navigation systems with associated costs and learning curves.
- **Lack of long-term outcomes**: Most studies are short-term and feature case reports; randomized controlled trials remain limited.

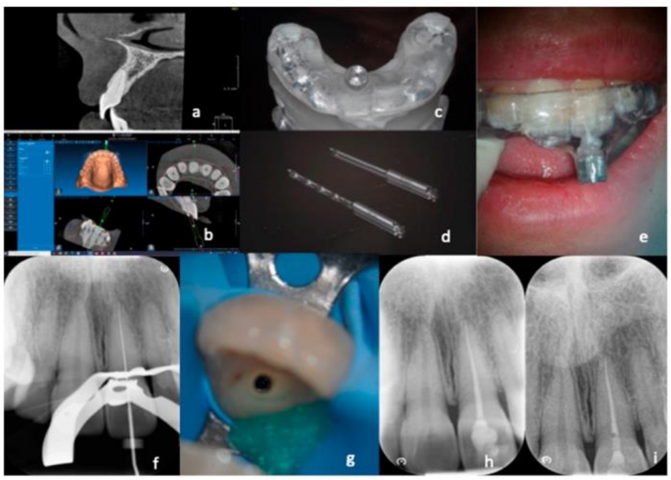

Figure 1

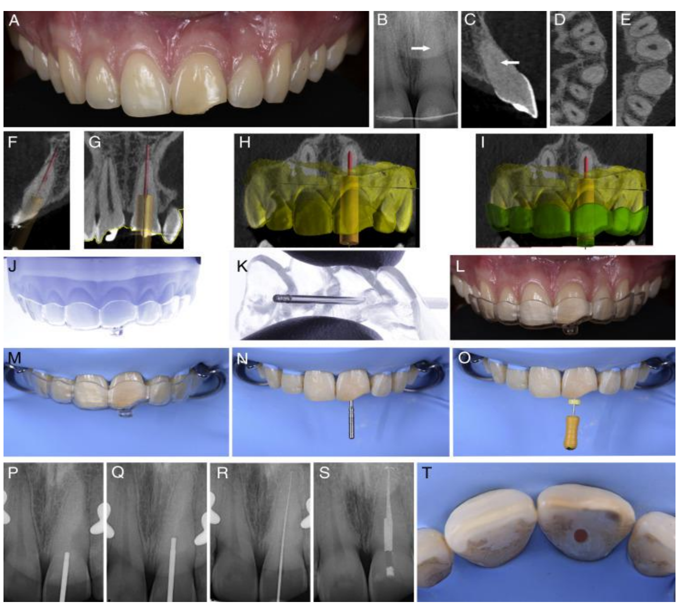

Figure 2

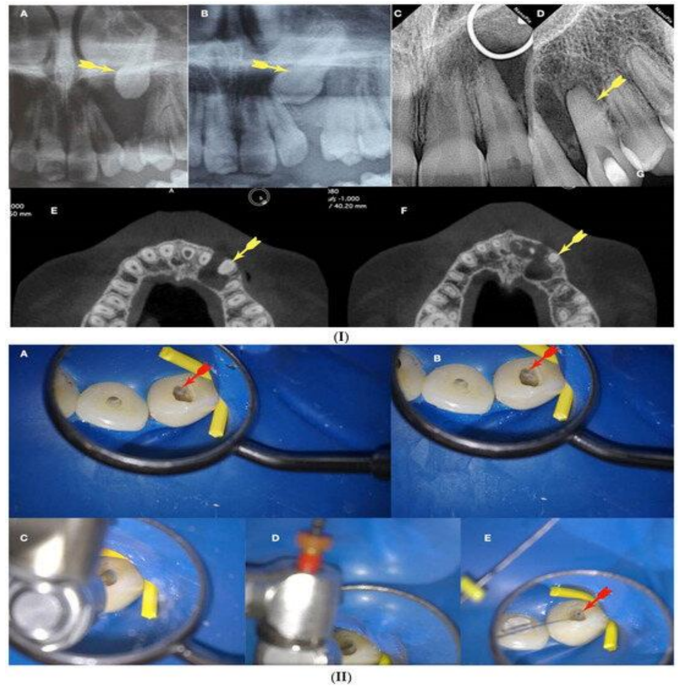

Figure 3

Below are detailed clinical examples and radiographic guides illustrating the use of guided endodontics for managing calcified canals:

Clinical & Radiographic Illustrations[14-18]

1. Static Guide Workflow (Clinical Example)

Visual sequence including CBCT imaging, digital planning, 3D-printed guide, drill insertion with depth control, rubber dam isolation, minimal dentin removal, obturation, and six-month follow-up radiograph.

2. CBCT-Guided Access Sequence

Composite image showing pre-operative photos; CBCT planning (axial/sagittal/coronal); drilling; access preparation; obturation; and radiographs demonstrating clinical progress.

3. Guided Treatment Steps

From pre-op radiograph and CBCT, through CAD design of surgical guide (static), to clinical drilling and post-operative obturation—with further follow-up CBCT confirming healing and accuracy.

4. Dynamic CBCT & Drilling Visualization

Overlay CBCT slices highlighting canal, drill path, surgical access, and clinical negotiation under magnification—emphasizes guided accuracy.

Key Clinical Insights[11, 17]

A. Guided Planning & 3D Design

- **CBCT imaging** identifies calcification depth/orientation.
- **Digital merging** with intraoral scans yields precise drill trajectories.
- **3D-static guides** (sleeved or open-frame titanium) constrain burs accurately, even in tight interocclusal spaces.

B. Conservative, Accurate Access

- Drill diameters range from 0.75–1.3 mm; guided depth control avoids overextension.
- Guided access markedly reduces dentin removal, preserving tooth strength.

C. Workflow & Safety

- Rubber dam isolation, verification of patency, and radiographic/CBCT confirmation ensure safe canal negotiation.

D. Addressing Failure & Deviations

- Some cases require supplemental microscope and ultrasonic techniques after initial miss—a "dynamic fallback" approach.

E. Guide Types & Selection

- Closed sleeve guides ensure stable drill alignment but limit visibility.
- Open-frame or titanium guides improve access, reduce saliva contamination, and lower costs.

Tips for Clinical Adoption[16-19]

Step	Description
Choose imaging carefuly	Use high-resolution CBCT (≤0.1 mm voxels)
Guide selection	Static for anterior teeth; open-frame for limited mouth opening
Burs & depth control	Small-diameter burs with stop; 10k rpm
Verify after drilling	Use magnification and radiographs during negotiation
Have backups ready	Ultrasound and microscope tools for canal localization failures

Conclusion

Guided endodontics represents a transformative solution for managing calcified and obliterated canals. With precision rates over 95%, significant dentin conservation, consistent performance regardless of clinician experience, and minimal complications, this technique should be considered when conventional access proves unpredictable. Nevertheless, clinicians must assess factors such as canal anatomy, mouth opening, and the availability of digital workflows. Future research should aim for longitudinal data and cost-benefit analyses to fully determine its role in everyday endodontic practice.

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