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Navigating Complex Endodontic Challenges: A Comprehensive Review of Guided Treatment Strategies

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ABSTRACT

The field of endodontics has undergone a significant transformation with the advent of guided techniques aimed at enhancing precision and predictability in managing complex cases. Conventional methods often fall short in scenarios involving calcified canals, developmental anomalies, or retreatments. This review explores the evolution and application of guided endodontic techniques, including static navigation, dynamic navigation, and guided microsurgical strategies. Through a synthesis of available literature and clinical cases, we highlight the indications, advantages, and current limitations of these approaches. Additionally, the article discusses future trends, including AI integration and advanced 3D printing, which may broaden the clinical accessibility and efficacy of guided endodontics. The review concludes by emphasizing the need for meticulous planning and proper case selection to maximize outcomes in complex endodontic scenarios.

Keywords: *Guided Endodontics, Static Navigation, Dynamic Navigation, CBCT in Endodontics*

1. INTRODUCTION

Complex endodontic cases, such as those involving pulp canal obliteration, anatomical anomalies, or surgical constraints, often challenge even experienced clinicians. Traditional diagnostic and operative tools, including radiographs, tactile sensation, and dental operating microscopes, may offer limited assistance in navigating these cases effectively[1] The risk of procedural mishaps, such as perforation or ledge formation increases with the complexity of the canal morphology and limited visibility[2]

In response to these challenges, guided endodontics has emerged as a precise, minimally invasive approach that leverages digital planning and advanced imaging. The integration of cone-beam computed tomography (CBCT) and computer-aided design/computer-aided manufacturing (CAD/CAM) has enabled practitioners to create static guides, while dynamic navigation systems allow for real-time adjustments during procedures[3]. This review aims to provide a comprehensive overview of guided endodontic treatment strategies, examining their indications, workflows, and future potential.

2. UNDERSTANDING COMPLEXITY IN ENDODONTICS

Anatomical Challenges in Endodontics

One of the most formidable aspects of complex endodontic treatment stems from anatomical variations and alterations within the root canal system. A primary concern is canal calcification, often seen in aging populations or as a response to trauma.

Calcified canals present with little to no visible canal lumen on radiographs, making canal negotiation exceptionally difficult. Pulp stones, which are discrete calcified masses within the pulp chamber, may obstruct canal orifices and prevent effective access. Similarly, developmental anomalies such as dens invaginatus and dens evaginatus pose unique anatomical challenges. Dens invaginatus presents as an invagination of enamel and dentin into the pulp space, increasing the risk of bacterial ingress and complicating root canal morphology. Dens evaginatus, on the other hand, features an accessory cusp that may fracture, exposing pulp and necessitating intricate endodontic therapy4. Furthermore, tortuous or highly curved canals can make instrumentation extremely challenging, increasing the risk of ledge formation, canal transportation, and instrument separation. In such cases, achieving a thorough biomechanical preparation without compromising the integrity of the canal becomes a significant concern, often requiring advanced imaging modalities and guided techniques for successful treatment.

Iatrogenic Factors Contributing to Complexity

In many instances, complexity in endodontic cases arises not solely due to natural anatomy, but due to procedural mishaps during prior treatments. Iatrogenic errors such as ledge formation, zipping, canal transportation, and perforations can drastically reduce the chances of favorable outcomes[5]. These issues often occur in cases where canal curvatures or aberrant anatomy are inadequately visualized or mismanaged with improper instrumentation techniques. A ledge, for example, may prevent access to the apical third of the canal, thereby impeding thorough debridement and obturation. Perforations, whether at the coronal, middle, or apical third pose an additional risk of microbial contamination and compromise the structural integrity of the tooth, often necessitating surgical intervention. Over-instrumentation and improper use of rotary systems can also weaken the canal walls, leading to vertical root fractures. Retreatment of such cases becomes increasingly complicated due to altered canal pathways, compromised tooth structure, and the presence of residual filling materials or broken instruments. These factors highlight the critical need for precise diagnostic imaging, enhanced visualization, and minimally invasive treatment planning, often facilitated through guided endodontics.

Diagnostic Challenges and Imaging Limitations

Traditional two-dimensional (2D) radiographic techniques, such as periapical radiographs, have long served as the cornerstone of endodontic diagnosis and treatment planning. However, 2D images suffer from significant limitations in complex cases due to their inability to accurately depict the three-dimensional (3D) configuration of root canal systems. Critical details such as accessory canals, apical deltas, canal bifurcations, and resorptive defects may go undetected on 2D films. Furthermore, superimposition of anatomical structures can mask pathology or mislead clinicians about canal curvature or length, leading to under-preparation or procedural errors. The lack of depth perception particularly hampers diagnosis in posterior teeth or in the presence of calcifications. These challenges often culminate in missed canals, inadequate cleaning, and subsequent treatment failure. Cone-beam computed tomography (CBCT) has addressed many of these shortcomings by providing high-resolution, volumetric data that can be manipulated in multiple planes[6]. CBCT is especially advantageous in complex cases, allowing for accurate mapping of canal trajectories, detection of periapical lesions, and assessment of treatment feasibility. Yet, even with advanced imaging, the translation of radiographic data into precise clinical execution remains difficult without guided techniques.

The Imperative for Precision and Predictability

In the realm of complex endodontics, the margin for error is exceedingly small, and the consequences of missteps are often irreversible. Precision in access cavity preparation, canal location, and cleaning is paramount to achieving successful treatment outcomes, particularly in cases with anatomic or iatrogenic complexity. Predictability in such procedures is also essential to enhance patient confidence and reduce operator stress. Conventional approaches that rely heavily on tactile feedback and visual interpretation, even when aided by dental operating microscopes, may not always suffice. The risk of overextending, missing canals, or damaging critical structures such as the furcation area or sinus floor necessitates a more sophisticated approach. Guided endodontics—whether through static navigation using pre-fabricated templates or dynamic systems offering real-time feedback—enhances both precision and predictability[7]. These systems allow clinicians to execute meticulously planned access trajectories with millimetric accuracy, thereby minimizing unnecessary dentin removal, preserving structural integrity, and improving clinical outcomes. Ultimately, the integration of digital planning, advanced imaging, and navigational technology represents a significant evolution in the management of complex endodontic cases, facilitating safer, more efficient, and more predictable treatment protocols.

Principles of Guided Endodontics

Guided endodontics represents a paradigm shift in the management of complex endodontic cases by integrating advanced imaging, digital planning, and precision instrumentation. Unlike conventional approaches that rely primarily on tactile sensation, two-dimensional radiographs, and clinician experience, guided endodontics offers a technology-driven pathway that enhances accuracy, conservatism, and predictability. This approach is particularly valuable in challenging clinical scenarios such as pulp canal obliteration, developmental anomalies, retreatment cases, or surgical endodontic procedures[8].

There are three primary modalities within guided endodontics:

Static Navigation (SN), Dynamic Navigation (DN), and Hybrid Approaches.

Static Navigation involves the use of cone-beam computed tomography (CBCT) and intraoral scanning to develop a precise three-dimensional model of the patient's dental anatomy. Digital planning software is then used to design the ideal trajectory for access cavity preparation, after which a customized, 3D-printed guide is fabricated[9]. This guide fits onto the patient's dentition and physically directs the bur along the planned path, ensuring millimetric accuracy. Static guides are especially effective in anterior teeth with pulp canal obliteration or when anatomical landmarks are compromised, as they eliminate guesswork and minimize the risk of perforation or unnecessary dentin removal.

In contrast, **Dynamic Navigation** systems offer real-time guidance during endodontic procedures using stereotactic tracking technology. These systems integrate preoperative CBCT data with intraoperative feedback to visually track the position of the bur in three-dimensional space relative to the planned path. Dynamic navigation is particularly advantageous in posterior teeth or cases where guide stabilization is difficult, such as limited mouth opening or complex angulation. It also allows for intraoperative adjustments, providing a level of flexibility absent in static systems.

Hybrid Approaches aim to leverage the strengths of both static and dynamic techniques. These may involve initial guide-based access followed by dynamic adjustments during deeper canal navigation or the integration of microscopic visualization to confirm procedural accuracy. Such combinations can be especially useful in multi-rooted teeth or surgical endodontics where both precision and intraoperative adaptability are required[10]

The **workflow of guided endodontics** follows a structured digital pathway[11]:

1. **CBCT Imaging**: High-resolution volumetric data is acquired to evaluate tooth morphology, canal location, and surrounding anatomical structures.
2. **Digital Planning**: Software platforms such as coDiagnostiX, Blue Sky Plan, or Navident are used to design the optimal path for canal access based on anatomical landmarks.
3. **Guide Fabrication**: For static navigation, a 3D printer is employed to manufacture a patient-specific guide that conforms precisely to the dentition and incorporates sleeves for drill orientation.
4. **Clinical Execution**: The endodontic procedure is performed using the static guide or under dynamic visualization, ensuring that access preparation aligns precisely with the preplanned trajectory while preserving sound tooth structure.

Through this integrated digital workflow, guided endodontics not only enhances the success rate of complex cases but also reduces procedural time, minimizes iatrogenic risks, and improves overall patient outcomes. As the field continues to evolve, the incorporation of artificial intelligence and machine learning into the planning phase may further refine accuracy and decision-making in guided endodontic therapy.

3. TREATMENT STRATEGIES USING GUIDED ENDODONTICS

The implementation of guided endodontic techniques has significantly advanced the ability of clinicians to address challenging cases that were once considered unpredictable or difficult to manage. The treatment strategies can be broadly categorized into static guided endodontics (SGE), dynamic navigation systems (DNE), guided microsurgical endodontics, and other innovative applications such as guided autotransplantation and intraosseous anesthesia delivery[12, 13, 14, 15]. Each approach leverages digital technologies to enhance precision, safety, and procedural efficiency.

a. Static Guided Endodontics (SGE)

Static guided endodontics employs pre-planned surgical templates based on CBCT data and intraoral scanning. These templates are designed using specialized software and fabricated through 3D printing technology. The guide fits onto the patient's dentition with a high degree of accuracy and directs the endodontic bur along a pre-determined trajectory, allowing for conservative and precise access cavity preparation.

Clinical Applications:

- **Calcified Anterior Teeth**: In cases of pulp canal obliteration due to trauma or age-related changes, SGE allows for minimally invasive canal location while preserving pericervical dentin. (Figure 1: A,B,C,D,E)
- **Trauma-Induced Canal Obliteration**: In teeth with completely obliterated canals, especially in young patients, SGE improves access without compromising tooth structure.
- **Developmental Anomalies**: Conditions such as **dens invaginatus**, where conventional access may be unpredictable, benefit greatly from this guided approach.

A calcified maxillary central incisor was successfully negotiated using a patient-specific 3D-printed guide, eliminating the risk of iatrogenic perforation and reducing chair time. The case demonstrated the effectiveness of static guidance in achieving precision without intraoperative errors.

b. Dynamic Navigation Systems (DNE)

Dynamic navigation involves real-time, computer-assisted guidance using stereotactic tracking systems such as Navident or X-Guide. Unlike static templates, DNE does not require pre-fabricated guides. Instead, a tracking system displays the drill trajectory on a screen, allowing for live visual feedback and intraoperative adjustments.

Clinical Applications:

- **Management of Calcified canal**s in both anterior and posterior teeth secondary to trauma, caries etc (Figure 2: A,B,C,D)
- **Retreatment Cases**: Altered anatomy from prior failed endodontic therapy often obscures canal location. DNE facilitates accurate re-navigation.
- **Posterior Teeth**: In patients with limited mouth opening or deep molar anatomy, dynamic systems are more adaptable than static guides.
- **Missed Canals**: Real-time tracking helps identify and access previously undetected canal systems.

Advantages:

- Offers **real-time visual guidance**, increasing accuracy in deep or curved access preparations.
- **Eliminates the need for 3D guide fabrication**, reducing preparation time and costs.
- Particularly **suited for posterior teeth** where guide stabilization is difficult or impossible.

Guided Microsurgical Endodontics (Figure 1: F,G,H,I,J,K & Figure 2-:E, F,G,H,I,J)

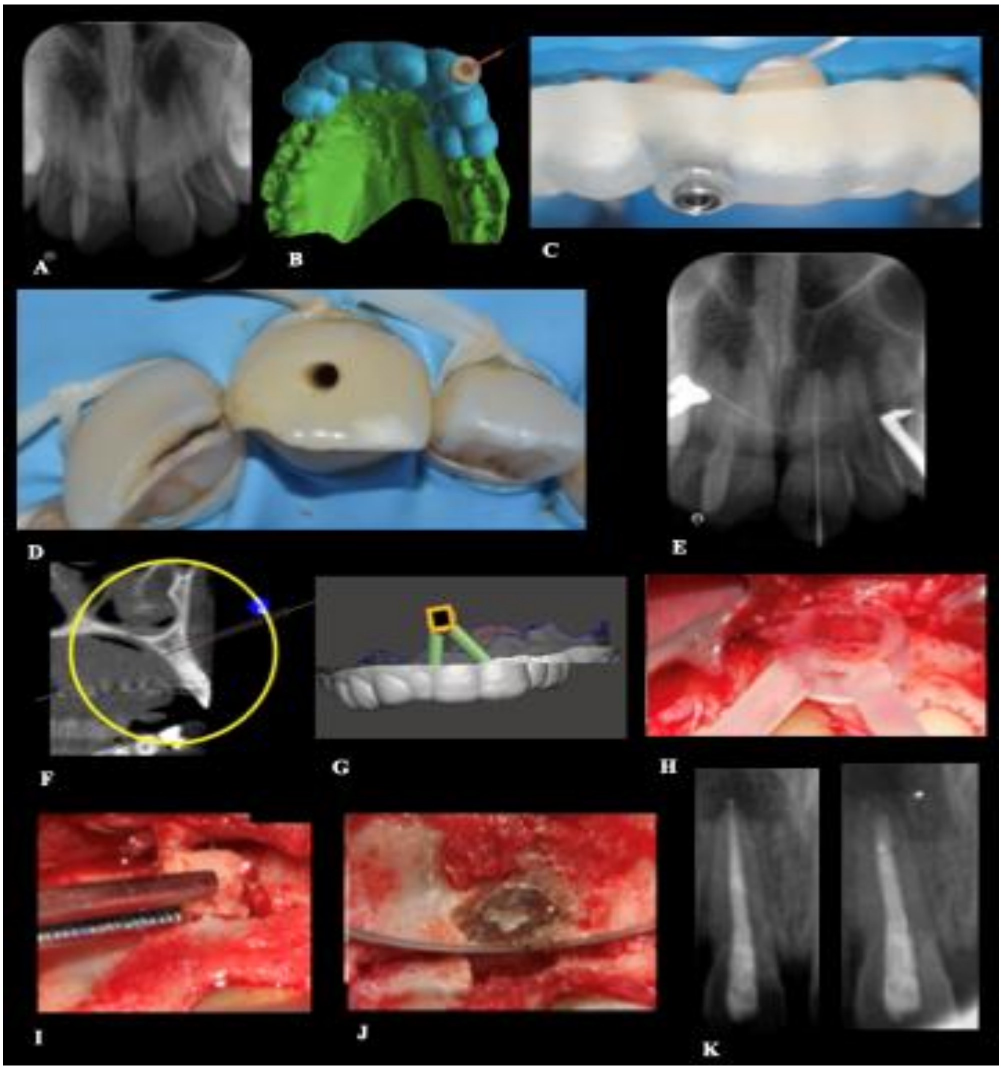

Figure 1: Static Guided Endodontics

A,B,C,D,E - Management of Calcified Canal

A. Pre operative radiograph showing calcification of 21
B. Virtual guide for angulation of drill
C. Guide in place following isolation
D. Access opening
E. Radiograph depicting negotiation of canal

F,G,H,I,J,K - Endodontic Microsurgery
F. Planning for precise location of cortical window
G. Virtual guide for the placement of the saw tip
H. Placement of the guide following reflection of flap
VI. Removal of the cortical bone
J. MTA placement
K. Pre Operative and Post Operative radiographs

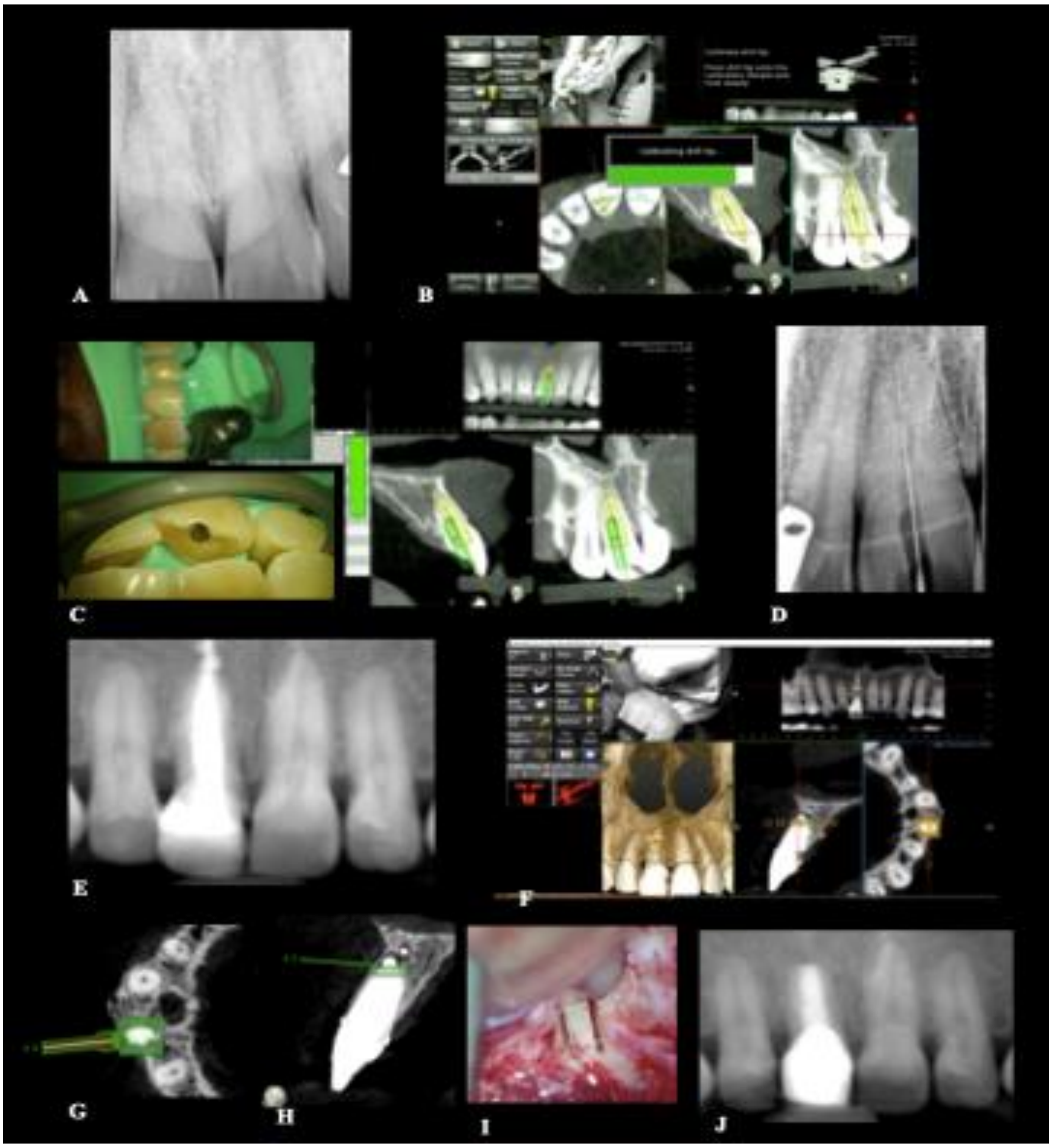

Figure 2: : Dynamic Guided Endodontics

A,B,C,D - Management of Calcified Canal

A. Pre operative radiograph showing calcification of 11

B. Planning on Navident II

C. Real time guide facilitating canal location

D. Radiograph depicting negotiation of canal

E,F,G,H,I,J - Endodontic Microsurgery

E. Pre Operative radiograph with periodical lesion following root canal

F. Planning for precise location of cortical window on Navident II

G,H. Real time guide guiding the saw tip

V. Bone window preparation

J. Post Operative radiographs

The precision of guided endodontics extends to surgical procedures as well. Microsurgical endodontics, such as apicoectomy or periapical curettage, benefits from targeted, minimally invasive approaches made possible by digital navigation. Static guides or dynamic systems can be employed to mark the location, angulation, and depth of osteotomy sites[16, 17, 18].

Clinical Applications:

- **Targeted Periapical Surgery**: For lesions located close to vital structures, guided access ensures minimal disruption and precise resection.
- **Fractured Instrument Retrieval**: Guided access paths to the apex can be planned for instrument removal.
- **Management of External Root Resorption**: Localized resorption defects can be approached conservatively with reduced risk of excessive bone removal.

Benefits:

- **Reduced bone loss** and surgical trauma due to precise targeting.
- **Enhanced healing** outcomes with minimal disruption to adjacent anatomical structures.
- **Shorter surgical durations** and improved patient comfort.

Other Applications of Guided Techniques

Beyond conventional and surgical endodontics, guided technology has expanded into innovative applications with promising clinical potential:

- **Guided Autotransplantation**: Using CBCT scans of the donor tooth, a 3D-printed replica can be created to prepare the recipient socket preoperatively. This enhances the success rate by ensuring optimal fit and reducing extra-oral time, which is critical for periodontal ligament viability[19].
- **Intraosseous Anesthesia Delivery**: In cases of failed conventional nerve blocks, especially in inflamed posterior teeth, guided techniques allow for accurate delivery of anesthetic solution directly into the cancellous bone adjacent to the root apex. Custom stents can be fabricated to direct the perforation site, thereby improving both safety and efficacy[20].

Guided endodontics continues to redefine the clinical approach to complex cases. Each modality—static, dynamic, or surgical—offers unique benefits that can be strategically selected based on clinical indications, patient anatomy, and the clinician’s skill set. As these technologies become more refined and accessible, they hold great promise in transforming endodontic care into a more precise and predictable discipline.

4. LIMITATIONS AND CHALLENGES

While guided endodontics has introduced a transformative approach in managing complex endodontic scenarios, it is not without its limitations. Despite the enhanced precision and predictability offered by static and dynamic navigation systems, several practical and technical barriers can limit their widespread adoption and consistent success in clinical practice[15, 18, 20]

High Initial Cost

One of the most significant barriers to the integration of guided endodontic systems is the substantial initial investment required. Cone-beam computed tomography (CBCT) units, digital intraoral scanners, planning software, and 3D printers represent a considerable financial burden, particularly for small or solo practices. Moreover, dynamic navigation systems such as Navident or X-Guide come with additional costs for equipment setup, licensing, and maintenance. The economic feasibility of guided endodontics must be weighed against its clinical advantages, especially in regions or practices with limited resources.

Technical Skill Requirement

Successful implementation of guided endodontic procedures requires a steep learning curve. Clinicians must acquire proficiency in several areas including CBCT interpretation, digital software planning, 3D design manipulation, and familiarity with both static and dynamic navigation systems. The process of integrating digital workflows into traditional clinical settings may be challenging, especially for practitioners who are not accustomed to using digital tools. Missteps in digital planning—such as incorrect path alignment or guide design—can lead to procedural errors, underscoring the need for thorough training and experience.

Intraoperative Errors and Guide Stability

Although designed to improve accuracy, guided endodontic systems are not immune to intraoperative complications. In static navigation, even minor discrepancies in guide fit, patient movement, or bur tolerance can lead to misalignment, resulting in perforation or failure to locate the canal. Similarly, in dynamic systems, calibration errors, tracker drift, or poor registration between the patient and the software can compromise the accuracy of real-time feedback. These issues demand vigilant attention to procedural protocols and frequent validation of the system's calibration during use.

Limited Application in Curved or Posterior Canals

Both static and dynamic guidance techniques face challenges in accessing severely curved canals or posterior teeth. Static guides are inherently linear and are best suited for straight-line access, which limits their applicability in complex canal morphologies. Designing guides for molars or teeth with restricted interocclusal space can be difficult due to the need for sufficient clearance and stabilization. Likewise, dynamic navigation may face constraints related to the tracking system's line of sight, especially in posterior regions where angulation and limited mouth opening complicate instrument maneuverability[21, 22]. In these cases, traditional tactile skills and microscope-assisted techniques may still offer greater flexibility[23].

Future Directions

As digital dentistry continues to evolve, the future of guided endodontics is poised to benefit from significant technological integration and innovation. The current trajectory points toward a more intelligent, accessible, and clinically adaptable framework, which could revolutionize how clinicians approach complex endodontic cases [3, 21].

Artificial Intelligence (AI) and Augmented Reality (AR)

One of the most anticipated advancements in guided endodontics is the incorporation of AI-driven tools for automated diagnosis and treatment planning. Machine learning algorithms, trained on large datasets of CBCT scans and clinical outcomes, could assist in identifying canal locations, predicting complex anatomy, and suggesting optimal access pathways. Augmented reality, meanwhile, may enhance intraoperative visualization by overlaying 3D anatomical structures directly onto the surgical field through head-mounted displays or digital microscopes. This could allow clinicians to perform procedures with a "see-through" effect, improving accuracy without relying solely on static or dynamic navigation screens.

Improved 3D Printing Technologies

The field of additive manufacturing is rapidly advancing, and its implications for guided endodontics are significant. Emerging 3D printing technologies promise faster production times, higher resolution, and more biocompatible materials. This could reduce turnaround times from digital planning to clinical execution, making same-day guided endodontic procedures feasible. Lower material and equipment costs may also make this technology more accessible to a wider range of dental practices, particularly in resource-limited settings.

Portable and Chairside Navigation Systems

The development of compact, portable dynamic navigation systems will be key in making guided endodontics more mainstream. Current dynamic systems can be bulky and require significant setup, limiting their adoption. The future may see lightweight, user-friendly units integrated directly into dental chairs or operating microscopes, with wireless instrumentation and simplified calibration processes. These innovations would enable seamless integration into daily practice and broaden clinical utility, especially for multi-chair clinics or mobile dental units.

Ongoing Research and Clinical Validation

Despite promising early outcomes, there is a need for larger, multicentric, and long-term studies to validate the efficacy and safety of guided endodontic techniques. Comparative trials between static, dynamic, and conventional methods are essential to establish evidence-based protocols and treatment guidelines. Research should also focus on quantifying patient-centered outcomes such as procedural time, post-operative discomfort, long-term success rates, and cost-effectiveness. Standardization in guide design, workflow steps, and navigation parameters will be crucial for training, regulation, and clinical reproducibility.

5. CONCLUSION

Guided endodontics represents a paradigm shift in the management of complex dental cases. By combining digital imaging, planning, and execution, it offers unparalleled precision, conservatism, and predictability. However, optimal outcomes depend on proper case selection, meticulous planning, and practitioner proficiency. As technology advances, guided endodontics is expected to become more accessible and integrated into mainstream endodontic practice, heralding a new era of precision dentistry.

REFERENCES

[1] McCabe PS, Dummer PM. Pulp canal obliteration: an endodontic diagnosis and treatment challenge. Int Endod J. 2012 Feb;45(2):177-97. doi: 10.1111/j.1365-2591.2011.01963.x. Epub 2011 Oct 17.

[2] Mahjourian Qomi R, Aminsobhani M, Assadian H, Adnaninia ST. Innovative Endodontic Management of Pulp Canal Obliteration in Mandibular Incisors Using a Static Navigation System: A Case Report. Clin Case Rep. 2024 Nov 20;12(11):e9596

[3] Moreno-Rabié C., Torres A., Lambrechts P., and Jacobs R., “Clinical Applications, Accuracy and Limitations of Guided Endodontics: A Systematic Review,” International Endodontic Journal 53, no. 2 (2020): 214–231.

[4] Ahmed HM. Anatomical challenges, electronic working length determination and current developments in root canal preparation of primary molar teeth. Int Endod J. 2013 Nov; 46(11):1011-22. doi: 10.1111/iej.12134. Epub 2013 May 25

[5] Permpongkosol S. Iatrogenic disease in the elderly: risk factors, consequences, and prevention. Clin Interv Aging. 2011;6:77-82. doi: 10.2147/CIA.S10252. Epub 2011 Mar 21.

[6] Deepak BS, Subash TS, Narmatha VJ, Anamika T, Snehil TK, Nandini DB. Imaging techniques in endodontics: an overview. J Clin Imaging Sci. 2012;2:13. doi: 10.4103/2156-7514.94227. Epub 2012 Mar 22. PMID: 22530184;

[7] Parinitha MS, Doddawad VG, Kalgeri SH, Gowda SS, Patil S. Impact of Artificial Intelligence in Endodontics: Precision, Predictions, and Prospects. J Med Signals Sens. 2024 Sep 2;14:25. doi: 10.4103/jmss.jmss_7_24.

[8] Kulinkovych-Levchuk K, Pecci-Lloret MP, Castelo-Baz P, Pecci-Lloret MR, Oñate-Sánchez RE. Guided Endodontics: A Literature Review. Int J Environ Res Public Health. 2022 Oct 26;19(21):13900. doi: 10.3390/ijerph192113900

[9] Hernández-Vigueras S., Rosas Mendez C., Christian Aravena P., Barria Rojas E., and Maldonado U. J., “Static Guided Endodontics, an Option for Pulpal Canal Obliteration. A Case Series,” International Journal of Morphology 40, no. 6 (2022): 1504–1510.

[10] Ribeiro D, Reis E, Marques JA, Falacho RI, Palma PJ. Guided Endodontics: Static vs. Dynamic Computer-Aided Techniques-A Literature Review. J Pers Med. 2022 Sep 15;12(9):1516.

[11] Leontiev W, Connert T, Weiger R, Dagassan-Berndt D, Krastl G, Magni E. Guided Endodontics: Three-dimensional Planning and Template-aided Preparation of Endodontic Access Cavities. J Vis Exp. 2022 May 24;(183). doi: 10.3791/63781. PMID: 35695531.

[12] Yang X., Zhang Y., Chen X., Huang L., and Qiu X., “Limitations and Management of Dynamic Navigation System for Locating Calcified Canals Failure,” Journal of Endodontics 50, no. 1 (2024): 96–105.

[13] Ribeiro D, Reis E, Marques JA, Falacho RI, Palma PJ. Guided Endodontics: Static vs. Dynamic Computer-Aided Techniques-A Literature Review. J Pers Med. 2022 Sep 15;12(9):1516. doi: 10.3390/jpm12091516. PMID: 36143301; PMCID: PMC9501573.

[14] Zehnder M.S., Connert T., Weiger R., Krastl G., Kühl S. Guided Endodontics: Accuracy of a Novel Method for Guided Access Cavity Preparation and Root Canal Location. Int. Endod. J. 2016;49:966–972. doi: 10.1111/iej.12544

[15] McCabe P.S., Dummer P.M.H. Pulp Canal Obliteration: An Endodontic Diagnosis and Treatment Challenge. Int. Endod. J. 2012;45:177–197. doi: 10.1111/j.1365-2591.2011.01963.x.

[16] Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. J Endod. 2006;32(7):601-623

[17] von Arx T, Walker WA 3rd. Microsurgical instruments for root-end cavity preparation following apicoectomy: a literature review. Endod Dent Traumatol 2000; 16(2):47–62.

[18] Frank C.Setzer, Sweta B.Shah, Meetu R.Kohli, BekirKarabucak, MS Syngcuk Kim. Outcome of Endodontic Surgery: A Meta-analysis of the Literature—Part 1: Comparison of Traditional Root-end 1. Surgery and Endodontic Microsurgery.J Endod Volume 36, Issue 11, November 2010, Pages 1757-1765

[19] Strbac, G.D. · Schnappauf, A. · Giannis, K.et al. Guided autotransplantation of teeth: a novel method using virtually planned 3-dimensional Templates J Endod. 2016; 42:1844-1850

[20] Sameer D. Jain ; Caroline K. Carrico; Ido Bermanis; Sonali Rehil. Intraosseous Anesthesia Using Dynamic Navigation Technology. J Endod Volume 46, Issue 12, December 2020, Pages 1894-1900

[21] Álvaro Zubizarreta-Macho, Sara Valle Castaño, José María Montiel-Company, Jesús Mena-Álvarez. Effect of Computer-Aided Navigation Techniques on the Accuracy of Endodontic Access Cavities: A Systematic Review and Meta-Analysis.Biology (Basel) 2021 Mar 10;10(3):212

[22] OA Peters Current challenges and concepts in the preparation of root canal systems: A reviewJ Endod 2004 3085596710.1097/01.don.0000129039.59003.9d

[23] BS Hema R Saxena KD Agrawal Methods to determine root canal curvatures and its managementsJ Res Adv Dent202010212632