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Dynamic Navigation in Endodontics: A Comprehensive Review of Principles, Applications, and Clinical Outcomes

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Abstract

Background:

Advances in digital dentistry have led to the development of guided technologies aimed at improving precision and predictability in endodontic procedures. Dynamic navigation systems (DNS) represent a novel approach that combines three-dimensional imaging with real-time instrument tracking.

Objective:

To critically evaluate the principles, clinical applications, accuracy, and challenges associated with dynamic navigation systems in endodontics.

Methods:

A narrative review of the literature was conducted using PubMed, Scopus, and Web of Science databases. Relevant in vitro studies, clinical trials, case reports, and systematic reviews were included.

Results:

Dynamic navigation integrates cone-beam computed tomography (CBCT) with real-time tracking, significantly improving procedural accuracy. Evidence suggests enhanced precision in access cavity preparation, endodontic microsurgery, and retreatment procedures, along with reduced iatrogenic errors and improved conservation of tooth structure.

Conclusion:

Dynamic navigation represents a shift toward precision-driven endodontics. Despite limitations such as cost and learning curve, it demonstrates strong potential for improving clinical outcomes.

Keywords: Dynamic navigation; guided endodontics; CBCT; minimally invasive dentistry; endodontic microsurgery

1. Introduction

Successful endodontic treatment relies on accurate identification of the root canal system and precise access cavity preparation. However, conventional techniques are inherently operator-dependent and primarily guided by tactile feedback and two-dimensional imaging. These limitations become particularly evident in teeth with pulp canal obliteration, complex anatomy, or previous endodontic treatment, where the risk of canal mislocation, excessive dentin removal, or procedural complications is increased.

In response to the growing emphasis on minimally invasive endodontics, there has been a shift toward technologies that enhance precision while preserving tooth structure. Guided endodontics has emerged as a valuable approach to address these challenges. Static guidance systems, based on cone-beam computed tomography (CBCT) data and three-dimensional printed templates, have demonstrated improved accuracy in canal localization. Nevertheless, their clinical application is limited by restricted intraoperative flexibility and reliance on preoperative planning.

Dynamic navigation systems (DNS) have been introduced to overcome these limitations by providing realtime, image-guided tracking of endodontic instruments. By integrating CBCT datasets with optical tracking technology, DNS enables continuous visualization of instrument position relative to the patient's anatomy, allowing intraoperative adjustments and improved control of angulation and depth. This real-time feedback has been associated with enhanced accuracy and reduced risk of iatrogenic errors.

The clinical relevance of DNS is most evident in challenging scenarios such as calcified canals, retreatment procedures, and endodontic microsurgery, where precision is critical for successful outcomes. In addition, the ability to preserve pericervical dentin aligns with current principles of minimally invasive endodontics.

Despite these potential advantages, the adoption of DNS remains limited due to factors including cost, technical complexity, and the need for clinician training. Furthermore, while preliminary studies have demonstrated promising results, long-term clinical evidence remains limited.

Therefore, the aim of the present review is to critically evaluate the principles, clinical workflow, applications, accuracy, and limitations of dynamic navigation systems in endodontics.

2. Evolution of Navigation in Endodontics

The concept of navigation-assisted operations originated in the field of neurosurgery, where precise localization within complex anatomical structures was essential. The stereotactic frame, a revolutionary invention created by Ernest A. Spiegel and Henry T. Wycis in 1947, enabled surgeons to utilize a threedimensional coordinate system to precisely target specific brain regions. This progress laid the groundwork for modern navigation systems and marked the beginning of image-guided surgery.

The accuracy of navigation systems was greatly improved over the ensuing decades by developments in imaging modalities like computed tomography (CT) and magnetic resonance imaging (MRI). These technologies made it easier to see anatomical structures and made it easier to integrate them with surgical tools. Because precise spatial orientation is crucial in other medical disciplines including orthopedics and otorhinolaryngology, navigation systems were gradually embraced in these fields.

The development of navigation systems was significantly expedited in the late 20th century with the advent of digital imagery and computer-assisted technologies. These developments were first used in dentistry in the field of implantology, where precise placement of dental implants is essential for both functional and cosmetic results. Cone-beam computed tomography (CBCT) is especially useful for dental applications because it offers three-dimensional image of the maxillofacial region with comparatively low radiation exposure.

Static navigation, which entailed creating surgical guides utilizing computer-aided design and computeraided manufacture (CAD/CAM) or 3D printing technology, was the mainstay of early dental guidance systems. Static guides increased accuracy, but their flexibility during procedures was limited since they could not adapt to intraoperative changes.

These constraints were addressed by dynamic navigation systems, which introduced real-time tracking capabilities. These systems continuously track the patient's and the surgical instrument's positions using optical or electromagnetic tracking devices. Clinicians can see how the instrument is positioned in relation to the patient's anatomy during the process by superimposing this information onto preoperative CBCT data.

Dynamic navigation was first used in dentistry for implant placement procedures, where research showed less departure from anticipated implant locations and increased accuracy. Motivated by these results, scientists and medical professionals investigated its use in endodontics, especially for difficult situations like pulp canal obliteration, intricate root canal structure, and endodontic microsurgery.

Dynamic navigation systems' performance and usability have improved recently due to ongoing advancements in both hardware and software. Higher tracking precision, better user interfaces, and better integration with digital workflows are all provided by modern systems. As a result, dynamic navigation has evolved from an experimental instrument to a clinically feasible technique with growing endodontic applications.

3. Search Strategy and Selection Criteria

A comprehensive literature search was performed to identify relevant studies on dynamic navigation in endodontics. Electronic databases, including PubMed, Scopus, and Web of Science, were searched for publications available up to 2025.

The search strategy incorporated combinations of keywords such as *“dynamic navigation,” “guided endodontics,” “calcified canals,” “endodontic microsurgery,”* and *“CBCT navigation.”* Reference lists of selected articles were also screened to identify additional relevant studies.

Studies were considered eligible if they included in vitro investigations, clinical studies, clinical trials, case reports, or systematic reviews focusing on the application of dynamic navigation in endodontics. Articles not published in English or lacking peer review were excluded.

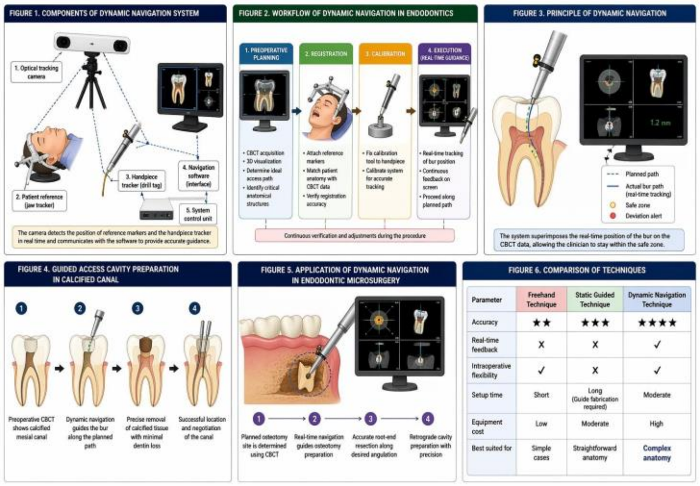
4. Principles of Dynamic Navigation

Dynamic navigation works by integrating CBCT imaging with optical tracking technology. The system continuously tracks the position of the dental handpiece and displays it on a screen relative to the patient’s anatomy.

This allows clinicians to:

- Follow a pre-planned path

- Make real-time corrections
- Reduce deviation from the target



The camera detects the position of reference markers and the handpiece tracker in real time and communicates with the software to provide accurate guidance.

The system superimposes the real-time position of the bur on the CBCT data, allowing the clinician to stay within the safe zone.

Parameter	Freehand Technique	Static Guided Technique	Dynamic Navigation Technique
Accuracy	★★	★★★	★★★★
Real-time feedback	X	X	✓
Intraoperative flexibility	✓	X	✓
Setup time	Short	Long (Guide fabrication required)	Moderate
Equipment cost	Low	Moderate	High
Best suited for	Simple cases	Straightforward anatomy	Complex anatomy

Figure 1. Comprehensive schematic representation of dynamic navigation in endodontics, including system components, workflow, principles, clinical applications, and comparison with conventional techniques

4. Components of Dynamic Navigation Systems

Dynamic navigation systems comprise a set of interconnected hardware and software elements that collectively enable real-time, image-guided endodontic procedures. These components establish a dynamic spatial relationship between the patient's anatomy, the preoperative imaging dataset, and the operative instruments, thereby enhancing procedural precision and control as illustrated in Fig. 2 and 3.

Tracking Camera

The tracking camera is a critical component that utilizes optical or infrared technology to detect the position of reference markers in three-dimensional space. It continuously monitors both the patient and the handpiece, enabling real-time tracking throughout the procedure.

Reference Markers

Reference markers, also known as fiducial markers, are attached to the patient to serve as stable spatial reference points. These markers allow the navigation system to align the patient's physical anatomy with the virtual CBCT dataset, ensuring accurate correspondence during treatment.

Handpiece Tracker

The handpiece tracker is mounted onto the dental handpiece and allows the system to monitor the position and angulation of the bur in real time. This facilitates precise execution of the planned trajectory and enhances operator control.

Calibration Tools

Calibration tools are used to establish the exact spatial relationship between the bur and the tracking system. Proper calibration is essential to ensure that the virtual representation of the instrument accurately reflects its actual position during the procedure.

Navigation Software

The navigation software serves as the central interface that integrates CBCT imaging data with real-time tracking information. It enables virtual treatment planning and provides continuous visual feedback, guiding the clinician during access preparation or surgical procedures.

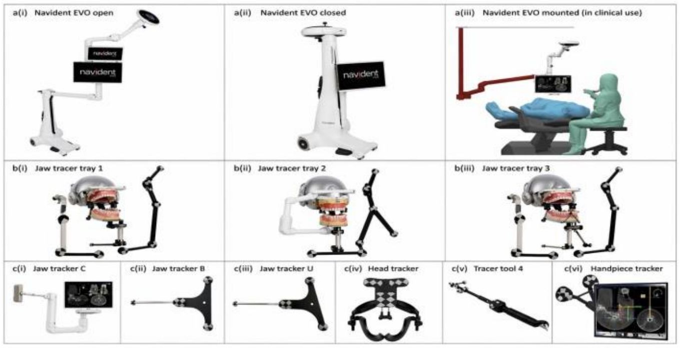


Figure 2. The components and configurations of the Navident EVO system – (a): (i) open, (ii) closed, (iii) mounted in clinical use; (b): (i–iii) jaw tracer trays 1, 2, and 3; (c): (i–vi) system accessories including jaw trackers, head tracker, tracer tool 4, and handpiece tracker.

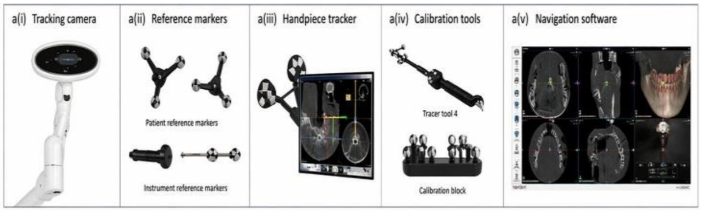


Figure 3. Schematic representation of the components of a dynamic navigation system (Navident EVO–type configuration) – (a): (i) tracking camera, (ii) reference markers, (iii) handpiece tracker, (iv) calibration tools, and (v) navigation software.

5. Clinical Workflow

The clinical workflow of dynamic navigation in endodontics involves a sequence of coordinated steps, beginning with digital planning and culminating in real-time guided execution. These steps ensure accurate correlation between the virtual CBCT dataset and the patient's actual anatomy, thereby enhancing procedural precision

1. Pre Operative Planning

The workflow begins with the acquisition and import of the patient's cone-beam computed tomography (CBCT) dataset into the navigation software. This enables a three-dimensional assessment of the tooth and surrounding anatomical structures. The software provides multiple viewing planes, including axial, sagittal, coronal, and reconstructed three-dimensional views, facilitating detailed evaluation. Based on this analysis, the clinician determines the optimal entry point, angulation, and depth for access preparation or surgical intervention.

2. Registration

Following planning, a tracking device is securely attached to the patient, typically in the form of a jaw or head tracker. A tracer tool is then used to map specific anatomical landmarks on the patient's dentition, allowing the system to align the physical anatomy with the CBCT dataset. This process establishes a precise spatial relationship between the virtual and clinical environments. An accuracy check is performed to confirm proper alignment before proceeding.

3. Calibration

In this step, the dental handpiece and bur are calibrated using specialized calibration tools. A tracking tag is attached to the handpiece, and the system determines the exact position and orientation of the bur tip. Accurate calibration is essential to ensure that the virtual representation of the instrument corresponds precisely to its actual position during the procedure.

4. Execution (Real-Time Navigation)

Once planning, registration, and calibration are completed, the procedure is carried out under real-time navigation guidance. The system continuously tracks the position of the bur relative to the patient's anatomy and displays it on the navigation screen. This allows the clinician to follow the preplanned path with high precision while making intraoperative adjustments as needed. Real-time feedback enhances control, reduces the risk of deviation, and supports minimally invasive access.

6. Literature Review

A comprehensive review of the available literature was undertaken to evaluate the current evidence regarding the application of dynamic navigation in endodontics. Relevant studies were identified through electronic databases including PubMed, Scopus, and Web of Science using combinations of keywords such as *dynamic navigation*, *guided endodontics*, *calcified canals*, *endodontic microsurgery*, and *computer-assisted dentistry*.

The search strategy included in vitro studies, clinical trials, case reports, and systematic reviews published in the English language. Studies focusing on applications of dynamic navigation in implantology alone, without relevance to endodontics, were excluded. Additionally, non-peer-reviewed articles and publications lacking sufficient methodological detail were not considered.

The selected studies were analysed based on their design, sample characteristics, type of navigation system used, and outcome measures such as accuracy, procedural time, deviation, and clinical success. Particular emphasis was placed on studies comparing dynamic navigation with freehand and static-guided techniques. Table 1. Summary of Studies on Dynamic Navigation in Endodontics

Author (Year)	**Study Type**	**Application**	**Key Findings**
Chong et al. (2019)	In vitro	Access cavity	Improved canal localization
Zubizarreta-Macho et al. (2020)	In vitro	Access cavity	Lower deviation vs static
Gambarini et al. (2020)	In vitro	Conservative access	Minimal dentin loss
Dianat et al. (2020)	In vitro	Calcified canals	Faster and accurate
Jain et al. (2020)		Access preparation	Reduced dentin loss
Connert et al. (2021)	In vitro	Access cavity	Reduced structure loss
Martinho et al. (2022)	Clinical	Microsurgery	Reduced time

7. Applications of Dynamic Navigation in Endodontics

Guided endodontic access

Peri-cervical dentin (PCD) is the dentin that is close to the alveolar crest. It is very important for the tooth's long-term survival because it helps it resist breaking. So, making a conservative access cavity is important for keeping PCD safe. Nevertheless, certain conditions complicate conservative access cavity preparation and result in the loss of valuable dentin, including pulp canal obliteration and dens invaginatus/evaginatus. DNS has recently been employed in these instances to establish a conservative access cavity preparation, circumventing the constraints of static-guided endodontics.

The navigation software shows the exact location of the tip of the bur in real time. This helps the operator find the canals in calcified cases and cases with multiple or unusual anatomy, which makes preparing the access cavity faster and more accurate. Dens invaginatus/evaginatus are developmental malformations that necessitate multiple precise and conservative access cavities to identify individual canals; DNS can be especially beneficial in these instances. The navigation system works with high-speed handpieces and precision micro-endodontic burs to make a minimally invasive, straight-line, and apically extended access cavity preparation. This saves the PCD and makes the tooth last longer in the mouth. Numerous in vitro studies comparing DNS to freehand access opening have determined that DNS facilitates the attainment of ultraconservative access cavities, reduces the risk of iatrogenic tooth substance loss, and requires less procedural time compared to the conventional freehand technique.

Endodontic microsurgery

Endodontic surgery is warranted subsequent to the failure of nonsurgical endodontic treatment and/or retreatment in specific cases of chronic apical periodontitis. Evidence-based literature indicates that endodontic microsurgery (EMS) boasts a high success rate of 94%, establishing it as a reliable and predictable treatment option for chronic apical periodontitis.

One of the biggest problems in surgical endodontics is making a bone cavity that is minimally invasive and has enough room for an accurate apicoectomy, retrograde filling, and curettage of the lesion.

Research indicates that DNS endodontic surgery produces a minimally invasive osteotomy site, accurate localization of the root, and precise root end resection with a 10° bevel angle due to the meticulous orientation of the bur in three dimensions, thereby mitigating the risk of iatrogenic error, even for less experienced practitioners. Unintended iatrogenic injury to adjacent anatomical structures can be minimized with dynamic navigation systems (DNS) owing to their real-time threedimensional visualization of the operative field. Additionally, electromagnetic surgery (EMS) utilizing DNS enables flapless procedures and allows for a precisely targeted, minimal osteotomy, which ultimately enhances postoperative healing and reduces patient discomfort.

Retreatment and Post Removal

Persistence of intra- and extraradicular microbial infection is a major reason for failure of primary endodontic treatment. Such cases typically require endodontic retreatment involving thorough debridement, shaping, disinfection, and three-dimensional obturation of the root canal system to achieve predictable outcomes.

However, teeth restored with posts present additional challenges during retreatment, as post removal carries a risk of iatrogenic complications. These may include unnecessary loss of sound tooth structure, development of microcracks leading to root fracture, deviation from the original canal path, and root perforation.

Conservative post removal is a highly technique-sensitive procedure that requires operator expertise along with magnification aids such as dental loupes or an operating microscope, in addition to ultrasonics. Recently, dynamic navigation systems (DNS) have been explored as an adjunct for real-time guidance during post removal, enabling visualization of the drill tip position and angulation with the ability to adjust the path intraoperatively—an advantage over static guides.

Bardales-Alcocer et al. reported nonsurgical retreatment through a zirconia bridge and fiber post using DNS and concluded that dynamic navigation facilitates minimally invasive post removal while reducing the risk of iatrogenic errors.

Foreign body removal

Computer-assisted dynamic navigation has demonstrated significant utility in the retrieval of foreign bodies such as fractured endodontic instruments, dental fragments, metallic objects, and even bullets. It serves as a precise and reliable modality with a high level of intraoperative accuracy for localizing and targeting the object. With the help of preoperative planning, removal can be performed through a minimally invasive access pathway, often in a shorter operative time.

Intraosseous anaesthesia

Achieving effective pulpal anaesthesia is a key requirement for successful endodontic treatment. Profound anaesthesia not only ensures patient comfort during root canal procedures but also helps the clinician manage patient response and prevent unexpected movements during treatment. However, attaining adequate anaesthesia can be challenging in certain situations, particularly in “hot tooth” cases.

Intraosseous anaesthesia is a supplemental technique with a high success rate and is often used in conjunction with inferior alveolar nerve blocks in such conditions. It involves the direct deposition of local anaesthetic into the cancellous bone adjacent to the affected tooth. Although effective, the procedure carries a risk of iatrogenic complications such as root perforation, improper cortical plate penetration, or fracture/separation of the delivery tip.

Jain et al. introduced a computer-aided dynamic navigation approach for intraosseous anaesthesia, where real-time control of the instrument’s position and angulation allows accurate perforation of the cortical bone and precise delivery of anaesthetic into the cancellous space, while minimizing the risk of damage to surrounding anatomical structures.

8. Comparison with Other Techniques

Parameter	**Freehand**	**Static**	**Dynamic**
Accuracy	Moderate	High	Very High
Flexibility	High	Low	High
Real-time feedback	No	No	Yes

9. Challenges in Implementation

Dynamic navigation in endodontics represents a significant advancement with the potential to improve procedural accuracy and overall treatment outcomes. Nevertheless, its clinical application is associated with several limitations. Key challenges include technological constraints, operator-related factors, patient-specific anatomical variations, financial burden, workflow integration, and the necessity for standardization and validation.

Technological limitations such as suboptimal imaging resolution, tracking inaccuracies, and software-related errors may reduce the precision of canal access and instrumentation guidance. In addition, operator expertise is essential for the effective use of these systems. Clinicians require dedicated training to correctly interpret navigation outputs and combine them with conventional endodontic techniques to prevent procedural complications.

Patient-related factors also influence the effectiveness of dynamic navigation. Variations in root canal anatomy, curvature, and calcification can make navigation difficult, requiring continuous intraoperative adjustments for accurate instrument control. Furthermore, patient movement and anatomical variability may further affect procedural stability and accuracy.

The high cost of equipment, software, and maintenance presents another significant barrier to widespread adoption. Limited reimbursement and insurance support further restrict accessibility in routine dental practice. From a workflow perspective, the requirement for detailed preoperative planning and intraoperative navigation may increase overall treatment time.

Additionally, robust validation and standardization are essential to establish the reliability and safety of dynamic navigation in endodontics. Well-designed clinical trials and long-term studies are needed to compare its outcomes with conventional methods in terms of success rates and durability. Effective collaboration among clinicians, researchers, engineers, and regulatory authorities is crucial for addressing these challenges and promoting clinical integration.

10. Future Directions

The continued development of dynamic navigation in endodontics is expected to significantly transform clinical practice, provided existing limitations are addressed. Several key areas may shape its future evolution:

Technological innovation: Ongoing improvements in navigation systems are essential to enhance precision and reliability. The incorporation of artificial intelligence may enable real-time optimization of guidance, thereby improving clinical decision-making and treatment efficiency.

Advanced visualization: The integration of augmented reality and virtual reality technologies can significantly improve anatomical visualization during procedures. These tools may provide immersive guidance and training environments, allowing more intuitive and accurate instrument navigation.

Portable systems: The development of compact and portable navigation units can facilitate their use in a wider range of clinical environments, including remote or mobile settings, thereby improving accessibility and procedural support.

Interdisciplinary collaboration: Progress in this field relies heavily on cooperation between endodontists, engineers, computer scientists, and material researchers. Contributions from robotics, imaging, and computational sciences can drive the creation of more efficient and customized navigation systems.

Clinical validation: Comprehensive clinical studies, including large-scale trials and systematic reviews, are essential to evaluate the safety, effectiveness, and cost-efficiency of dynamic navigation compared to conventional techniques, supporting its evidence-based adoption in routine practice.

11. Discussion

Dynamic navigation systems (DNS) represent a significant advancement in endodontic practice by combining digital imaging with real-time procedural guidance. The findings from the present review indicate that DNS consistently demonstrates higher accuracy compared to conventional freehand techniques, particularly in challenging clinical scenarios such as pulp canal obliteration and complex root canal morphology.

One of the most notable advantages of DNS is its ability to provide real-time feedback during procedures. Unlike static navigation systems, which rely on pre-fabricated guides and lack intraoperative flexibility, DNS allows clinicians to make immediate adjustments to angulation and depth. This feature is particularly beneficial in cases where anatomical variations or unexpected intraoperative challenges are encountered.

The evidence analyzed in this review suggests that DNS significantly reduces angular and linear deviations during access cavity preparation. This improved precision contributes to better localization of root canals and minimizes unnecessary removal of tooth structure. Preservation of pericervical dentin is a key factor in maintaining tooth strength, and DNS supports this principle by enabling conservative access designs.

Another important application of DNS is in endodontic microsurgery. The ability to accurately perform osteotomy and root-end resection while minimizing damage to surrounding tissues enhances surgical outcomes and promotes faster healing. Additionally, DNS has shown promising results in retreatment procedures, particularly in the removal of fiber posts, where accurate angulation is critical to avoid complications such as perforation.

Despite these advantages, several limitations must be considered. The high cost of dynamic navigation systems remains a major barrier to widespread adoption, especially in routine clinical practice. Furthermore, the technology requires a certain level of technical expertise, and clinicians must undergo training to become proficient in its use. A learning curve is therefore inevitable, and initial procedure times may be longer.

Another limitation is the reliance on CBCT imaging, which introduces concerns related to radiation exposure and image quality. Errors in image acquisition or registration can directly affect navigation accuracy. Additionally, patient movement during the procedure may compromise tracking precision.

A critical observation from the literature is that the majority of available studies are in vitro or conducted under controlled conditions. While these studies provide valuable insights into the accuracy of DNS, they may not fully replicate clinical complexities. There is a relative lack of longterm randomized clinical trials evaluating treatment outcomes, which highlights the need for further research.

From a broader perspective, dynamic navigation reflects the ongoing transition toward digital and precision-based dentistry. As technologies such as artificial intelligence and augmented reality continue to evolve, their integration with DNS has the potential to further enhance clinical decisionmaking and procedural accuracy.

12. Conclusion

Dynamic navigation systems have introduced a new level of precision and predictability in endodontic practice by enabling real-time, image-guided procedures. The evidence reviewed in this article demonstrates that DNS offers superior accuracy compared to conventional freehand techniques and provides significant advantages in complex clinical situations, including calcified canals, retreatment procedures, and endodontic microsurgery.

The technology supports the principles of minimally invasive dentistry by facilitating conservative access cavity preparation and preserving critical tooth structure. Additionally, its ability to provide continuous feedback enhances clinician confidence and reduces the likelihood of procedural errors.

However, despite its promising potential, the widespread adoption of dynamic navigation is currently limited by factors such as high cost, technical complexity, and the need for specialized training. Furthermore, the existing body of evidence is predominantly based on in vitro studies, emphasizing the need for well-designed clinical trials with long-term follow-up.

In conclusion, dynamic navigation represents a paradigm shift in endodontics, moving toward a more precise, digitally driven approach to treatment. With ongoing technological advancements and increasing clinical experience, DNS is likely to play an increasingly important role in modern endodontic practice.

13. References

1. Chong BS, Dhesi M, Makdissi J. Computer-aided dynamic navigation: A novel method for guided endodontics. Quintessence Int. 2019;50:196–202.
2. Zubizarreta-Macho Á, Muñoz AP, Deglow ER, Agustín-Panadero R, Álvarez JM. Accuracy of computer-aided dynamic navigation compared to static procedure. J Clin Med. 2020;9:129.
3. Spiegel EA, Wycis HT, Marks M, Lee AJ. Stereotaxic apparatus for brain surgery. Science. 1947;106:349–350.
4. Gupta S, Patil N, Solanki J, Singh R, Laller S. Oral implant imaging: A review. Malays J Med Sci. 2015;22:7–17.
5. Jorba-García A, Figueiredo R, González-Barnadas A, Camps-Font O, Valmaseda-Castellón E. Accuracy in dynamic guided implant surgery. Med Oral Patol Oral Cir Bucal. 2019;24:e76–83.
6. Gambarini G, Galli M, Morese A, et al. Precision of dynamic navigation in ultraconservative access cavities. J Endod. 2020;46:1286–1290.
7. Dianat O, Nosrat A, Tordik PA, et al. Accuracy of dynamic navigation in locating calcified canals. J Endod. 2020;46:1719–1725.
8. Jain SD, Carrico CK, Bermanis I. Accuracy of dynamic navigation in calcified canals. J Endod. 2020;46:839–845.

9. Jain SD, Saunders MW, Carrico CK, et al. Dynamic vs freehand access cavity preparation. J Endod. 2020;46:1745–1751.
10. Connert T, et al. Real-time guided endodontics vs conventional techniques. J Endod. 2021;47:1651–1656.
11. Dianat O, et al. Guided root-end resection using dynamic navigation. Int Endod J. 2021;54:793–801.
12. Aldahmash SA, et al. Dynamic navigation in endodontic microsurgery. J Endod. 2022;48:922– 929.
13. Martinho FC, et al. Accuracy of DNS in microsurgery. J Endod. 2022;48:1327–1333.
14. Janabi A, et al. Dynamic navigation for fiber post removal. J Endod. 2021;47:1453–1460.
15. Martinho FC, et al. Dynamic navigation in post removal. J Endod. 2024;50:844–851.
16. Xing L, et al. CT navigation for foreign body removal. Int J Oral Maxillofac Surg. 2015;44:322–328.
17. Philbert R, et al. Navigation-assisted foreign body management. J Oral Maxillofac Surg. 2014;72:653.
18. Jain SD, et al. Intraosseous anesthesia using DNS. J Endod. 2020;46:1894–1900.
19. Vasudevan A, et al. Dynamic navigation systematic review. Eur Endod J. 2022;7:81–91.
20. Hultin M, et al. Computer-guided surgical advantages. Clin Oral Implants Res. 2012;23:124– 135.