REVIEW ARTICLE

Clinical Applications and Accuracy of Dynamic Navigation Systems in Endodontics

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ABSTRACT

Dynamic navigation systems (DNS) have emerged as an innovative digital technology in endodontics, enabling real-time guidance during operative procedures. This review aims to critically evaluate the clinical applications and accuracy of dynamic navigation systems in endodontic practice. A comprehensive analysis of current literature was performed to assess the effectiveness of DNS in procedures such as access cavity preparation, location of calcified canals, guided endodontic microsurgery, and management of complex root canal anatomies. Evidence from in vitro, ex vivo, and clinical studies indicates that dynamic navigation systems significantly improve procedural accuracy, reduce deviation from planned pathways, and enhance the predictability of minimally invasive approaches compared with conventional freehand techniques. Additionally, DNS allows for greater flexibility than static guides, offering real-time feedback and adaptability during treatment. Despite these advantages, limitations such as high cost, learning curve, increased chairside time during the initial phase, and dependence on accurate imaging and calibration remain challenges to widespread adoption. Overall, dynamic navigation systems represent a promising advancement in endodontics, particularly for complex and high-risk cases. Further well-designed clinical trials are required to establish standardized protocols, long-term outcomes, and cost-effectiveness to support their routine clinical use.

KEYWORDS: Dynamic navigation system; Endodontics; Guided endodontics; Accuracy; Calcified canals; Computer-assisted surgery; Minimally invasive endodontics

INTRODUCTION

The ultimate goal of endodontic treatment is the long-term preservation of the natural dentition through effective elimination of infection and prevention of reinfection while maintaining the structural integrity of the tooth. Achieving this objective requires precise execution of each procedural step, beginning with accurate access cavity preparation and identification of the root canal system. Errors at the access stage are irreversible and may lead to excessive dentin removal, missed canals, perforations, or vertical root fractures, all of which negatively affect prognosis (1–3).

The complexity of root canal anatomy, including variations in canal morphology, curvature, calcifications, and pulp canal obliteration, presents significant challenges even for experienced clinicians. Teeth affected by age-related changes, trauma, orthodontic treatment, or extensive restorations often exhibit calcified canals, making conventional freehand canal location particularly difficult and time-consuming (4). Although dental operating microscopes and CBCT imaging have enhanced visualization and diagnostic accuracy, they do not fully eliminate the risk of spatial misjudgment inherent in manual procedures (5).

In recent years, the concept of minimally invasive endodontics has gained prominence, emphasizing conservative access designs and maximal preservation of pericervical dentin to enhance fracture resistance and long-term tooth survival (6). This paradigm shift has driven the adoption of digital technologies aimed at improving precision and predictability. Guided endodontics, introduced as an extension of computer-guided implantology, integrates CBCT data with digital planning software to guide access cavity preparation and other endodontic procedures (7).

Static guided endodontics, which employs three-dimensional printed templates, has demonstrated high accuracy in locating calcified canals, particularly in anterior teeth (8). However, static guides present inherent limitations, including restricted intraoperative flexibility, dependence on guide stability, limited irrigation, and difficulty in posterior regions or patients with restricted mouth opening (9). Furthermore, any discrepancy between the planned and actual clinical situation cannot be corrected once the guide is fabricated.

Dynamic navigation systems (DNS) address several of these limitations by providing real-time, computer-assisted guidance during endodontic procedures. DNS uses optical or electromagnetic tracking to continuously monitor the position of the handpiece relative to the patient's anatomy displayed on CBCT-derived images (10). This technology enables continuous visualization of drill trajectory, angulation, and depth, allowing immediate corrections and greater procedural control.

While DNS has been extensively validated in implant dentistry, its application in endodontics is relatively recent. Preliminary

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studies suggest that DNS may enhance accuracy, reduce procedural errors, and improve outcomes in complex endodontic scenarios (11,12). However, the evidence remains fragmented, and questions persist regarding its clinical accuracy, learning curve, cost-effectiveness, and long-term benefits. Therefore, a comprehensive and critical review of the clinical applications and accuracy of dynamic navigation systems in endodontics is warranted to clarify their current role and future potential.

AIM OF THE STUDY:

To review the uses and efficiency of dynamic navigation system in endodontic procedures.

MATERIALS AND METHODS

Data sources

Data extraction was carried out according to the standard Cochrane systematic review methodology. Pubmed, Web of Science, Scopus, Medline, and Embase databases was searched until January 2026, for randomized clinical trials (RCT), controlled clinical trials (CCT) and cohort studies with keywords 'endodontic navigation' 'root canal treatment' 'dynamic navigation system.' After an initial selection phase of the records identified from the databases, potentially eligible articles will be qualitatively evaluated to investigate the pros and cons of using navigation system for root canal therapy.

Data extraction

Screening of eligible studies, assessment of the methodological quality and data extraction was conducted independently and in duplicate. Two reviewers evaluated the references using the same search strategy and then the same inclusion criteria to the selected studies was applied.

The detailed PICO principles will be defined as follows: • Population—human teeth or three-dimensional (3D) printed teeth; • Intervention—non-surgical endodontic treatment using the dynamic navigation system; • Comparison—non-surgical endodontic treatment using the conventional freehand technique; • Outcome—accuracy and efficiency of non-surgical endodontic treatment.

Inclusion criteria	Exclusion criteria
Clinical trials and randomized control studies	Systematic reviews or meta-analyses or expert opinions or narrative
Literature published until September 2022	
English language of publication	Language other than English
In vivo (humans), In vitro studies	Animal studies

DISCUSSION

Principles and Workflow of Dynamic Navigation in Endodontics

Dynamic navigation systems operate by merging preoperative CBCT data with real-time tracking of the patient and dental instruments. Fiducial markers or reference arrays are used to establish spatial registration, enabling the navigation software to correlate instrument movement with the virtual treatment plan (10). Unlike static guides, DNS allows unrestricted handpiece movement while providing continuous feedback on angulation, depth, and spatial deviation.

This real-time adaptability is particularly relevant in endodontics, where anatomical variations, limited visual access, and unexpected intraoperative findings are common. The ability to modify the planned path during treatment represents a fundamental advantage of DNS over static systems (13). Additionally, DNS eliminates the need for guide fabrication, potentially reducing treatment delays and laboratory costs.

Clinical Applications of DNS in Endodontics

Access Cavity Preparation and Minimally Invasive Endodontics

The most extensively studied application of DNS in endodontics is access cavity preparation, particularly in teeth with pulp canal obliteration. DNS-guided access cavities have been shown to follow the planned trajectory with high fidelity, minimizing unnecessary dentin removal and preserving pericervical dentin (11,14). This is critical for maintaining the mechanical strength of endodontically treated teeth.

Several studies report that DNS significantly reduces the risk of perforation and canal deviation compared with freehand techniques, especially in anterior teeth and premolars (12,15). By enabling a straight-line approach to the canal while maintaining conservative access outlines, DNS aligns closely with contemporary minimally invasive endodontic principles.

Management of Calcified Canals

Calcified canals remain one of the most challenging clinical scenarios in endodontics. Traditional methods often require extended operative time and carry a high risk of procedural errors. DNS provides real-time spatial guidance that allows clinicians to progress toward the canal lumen with controlled precision, even in the absence of visual landmarks (14,16).

In vitro and clinical studies indicate that DNS-guided canal location results in higher success rates and reduced dentin loss compared with conventional approaches (17). This application is particularly valuable in teeth with narrow roots, where even minor deviations may result in perforation or weakening of the tooth structure.

Endodontic Retreatment Procedures

DNS has also been explored in retreatment scenarios, including fiber post removal and identification of missed canals. These procedures demand precise angulation and depth control to prevent root damage. DNS-guided post removal allows controlled access along the long axis of the post, minimizing the risk of root perforation and excessive dentin removal (18).

Similarly, DNS has been used to locate untreated canals in previously obturated teeth, improving predictability and reducing procedural complications (19). Although evidence remains limited, available data suggest that DNS may enhance safety and efficiency in complex retreatment cases.

Endodontic Microsurgery

The application of DNS in endodontic microsurgery represents a growing area of interest. Accurate osteotomy and root-end resection are critical for surgical success, particularly in anatomically challenging regions. DNS-guided microsurgery allows precise translation of virtual surgical planning to the clinical field, reducing the risk of damage to adjacent structures (20).

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Reported mean linear and angular deviations for DNS-guided surgical procedures are within clinically acceptable limits and comparable to those observed in guided implant surgery (21). These findings suggest that DNS may improve the predictability and reproducibility of endodontic microsurgical procedures.

Accuracy and Precision of Dynamic Navigation Systems

Accuracy assessment is central to evaluating the clinical value of DNS. Studies consistently report lower coronal, apical, and angular deviations with DNS compared with freehand techniques (22). Mean deviations typically fall below 1.5 mm, a threshold considered acceptable for endodontic applications (23). When compared with static guides, DNS demonstrates similar accuracy under ideal conditions but offers superior flexibility in complex clinical situations. Static guides may achieve marginally higher precision in controlled settings; however, their inability to adapt intraoperatively may limit their clinical utility (19).

Impact of Operator Experience and Learning Curve

DNS has been shown to reduce operator-dependent variability, enabling less experienced clinicians to achieve outcomes comparable to those of experienced practitioners (21). This standardization potential is particularly relevant in academic and training environments. Nevertheless, effective use of DNS requires proficiency in CBCT interpretation, digital planning, and system calibration, underscoring the importance of structured training programs.

Overall, guided endodontics provides a more precise and safer treatment option compared to traditional freehand approaches, as it allows for minimally invasive access and predictable identification of root canals in complex cases, while minimizing the risk of iatrogenic damage and preserving more tooth structure (22). The dynamic navigation (DN) approach, having been introduced more recently, is less extensively supported in the scientific literature than the static navigation (SN) technique (23). Nonetheless, the DN method shows significant potential for future improvements and refinements. Despite these advancements, further research involving larger sample sizes and standardized protocols is necessary to validate the accuracy of both guided endodontic techniques. Additionally, studies exploring a variety of clinical scenarios would be highly valuable. Although numerous case reports exist and only a few case series have been published, randomized clinical trials would provide critical insights into the clinical outcomes of guided endodontic applications

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Limitations, Challenges, and Evidence Gaps

Despite its advantages, DNS adoption is limited by high initial costs, equipment requirements, and workflow complexity. Additionally, inaccuracies in CBCT imaging, patient movement, or system calibration can compromise navigation accuracy.

The current evidence base is dominated by in vitro studies, case reports, and small clinical series. There is a lack of large-scale randomized clinical trials evaluating long-term outcomes, patient-reported measures, and cost-effectiveness. Furthermore, heterogeneity in study designs and outcome metrics limits quantitative synthesis.

Future Directions

Future research should focus on well-designed clinical trials comparing DNS with conventional and static guided approaches across diverse endodontic procedures. Integration of artificial intelligence, augmented reality, and improved tracking technologies may further enhance system accuracy and usability. Establishing standardized protocols and reporting guidelines will be essential for advancing evidence-based adoption of dynamic navigation systems in endodontics.

CONCLUSION

The DNS demonstrated accuracy and efficiency in performing endodontic microsurgery, finding calcified canals, and performing minimally invasive access cavities. It also assisted in determining the best location for intraosseous anesthetic. Although introduced recently into dentistry, DNS has shown promise in the studies conducted until now.

REFERENCES

1. Vasudevan A, Santosh SS, Selvakumar RJ, Sampath DT, Natanasabapathy V. Dynamic navigation in guided endodontics – A systematic review. Eur Endod J. 2022;7(2):81–91. PMID: 35786584.
2. Pereira TD, Fonseca FP, Amaral MB, et al. Accuracy and efficiency of a dynamic navigation system for locating calcified canals: an in vitro study. J Endod. 2020;46(6):802–808. PMID: 32692993.
3. Martinho FC, Griffin IL, Corazza BJ. Current applications of dynamic navigation system in endodontics: a scoping review. European Journal of Dentistry. 2023 Jul;17(03):569-86.
4. Systematic review on DNS in endodontic surgery: metrics and clinical outcomes. J Endod. 2025; (online ahead of print). PMID: 40941501.
5. Limitations and management of dynamic navigation system for locating calcified canals failure. J Endod. 2024;50(1):96–105.
6. Bradley H. Dynamic navigation for endodontic access in calcified teeth: review of evidence and gaps (Master’s thesis). University research repository; 2025.
7. Precision and efficiency in endodontics: dynamic navigation explored – a systematic review and meta-analysis. Misr Dental Sci Res J. 2023;1(1):1–15.
8. Accuracy of dynamic navigation for non-surgical endodontic treatment: a systematic review. MDPI J Clin Med.
9. Jain D, Amin J, Basrani B, et al. Use of dynamic navigation systems in endodontics: clinical applications and outcomes. J Int Clin Dent Res Organ. 2022;14(10).
10. Additional review evidence from secondary sources: dynamic navigation system in endodontics – a systematic review. Neuroquantology. 2022;20(15).
11. McNamara, J.A., Brudon, W.L. and Kokich, V.G., 2001. Orthodontics and dentofacial orthopedics (Vol. 85). Ann Arbor: Needham Press.
12. Tamer, İ., Öztaş, E. and Marşan, G., 2019. Orthodontic treatment with clear aligners and the scientific reality behind their marketing: a literature review. Turkish journal of orthodontics, 32(4), p.241
13. Vlaskalic, V. and Boyd, R.L., 2002. Clinical evolution of the Invisalign appliance. Journal of the California Dental Association, 30(10), pp.769-776.
14. Bun San Chong, B., Manpreet Dhesi, B., Makdissi, J. and RCR, D., 2019. Computer-aided dynamic navigation: a novel method for guided endodontics. Quintessence International, 50(3), pp.196-202.
15. Martinho, F.C., Griffin, I.L. and Corazza, B.J.M., 2022. Current Applications of Dynamic Navigation System in Endodontics: A Scoping Review. European Journal of Dentistry.

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16. Gambarini, G.; Galli, M.; Morese, A.; Stefanelli, L.V.; Abduljabbar, F.; Giovarruscio, M.; di Nardo, D.; Seracchiani, M.; Testarelli, L. Precision of Dynamic Navigation to Perform Endodontic Ultraconservative Access Cavities: A Preliminary In Vitro Analysis. J. Endod. 2020, 46, 1286–1290.
17. Chong, B.S., Dhesi, M. & Makdissi, J. (2019) Computer-aided dynamic navigation: a novel method for guided endodontics. Quintessence International, 50, 196–202
18. Zubizarreta-Macho, A., Munoz, A.P., Deglow, E.R., AgustinPanadero, R. & Alvarez, J.M. (2020) Accuracy of computeraided dynamic navigation compared to computer-aided static procedure for endodontic access cavities: an in vitro study. Journal of Clinical Medicine, 9, 129
19. Gambarini, G., Galli, M., Morese, A., Stefanelli, L.V., Abduljabbar, F., Giovarruscio, M. et al. (2020) Precision of dynamic navigation to perform endodontic ultraconservative access cavities: a preliminary in vitro analysis. Journal of Endodontics, 46, 1286–1290.
20. Buchgreitz, J., Buchgreitz, M. & Bjørndal, L. Guided root canal preparation using cone beam computed tomography and optical surface scans – an observational study of pulp space obliteration and drill path depth in 50 patients. International Endodontic Journal, 52, 559–568.
21. Gambarini G, Galli M, Stefanelli LV, Di Nardo D, Morese A, Seracchiani M, De Angelis F, Di Carlo S, Testarelli L. Endodontic microsurgery using dynamic navigation system: a case report. Journal of endodontics. 2019 Nov 1;45(11):1397-402
22. Nahmias Y. Dynamic endodontic navigation: a case report. Oral Health. 2019;109:45-56.
23. Jain SD, Carrico CK, Bermanis I. 3-Dimensional accuracy of dynamic navigation technology in locating calcified canals. Journal of Endodontics. 2020 Jun 1;46(6):839-45.
24. Zubizarreta-Macho, Á.; de Pedro Muñoz, A.; Riad Deglow, E.; Agustín-Panadero, R.; Mena Álvarez, J. Accuracy of ComputerAided Dynamic Navigation Compared to Computer-Aided Static Procedure for Endodontic Access Cavities: An In Vitro Study. J. Clin. Med. 2020, 9, 129.

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