



# Guided Endodontics: A Comprehensive Review of Static and Dynamic Navigation Systems

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## ABSTRACT:

Guided endodontics is a leading advancement in digital dentistry, revolutionising root canal treatment. This innovative approach significantly enhances precision in canal localisation, access cavity preparation, and overall treatment outcomes. A core principle of modern dentistry is preservation, emphasising minimal trauma to healthy surrounding tissues. Digital dentistry facilitates this by capturing impressions of vital structures using digital scans, such as cone-beam computed tomography (CBCT) and intraoral scanners. The resulting three-dimensional (3D) image assists in diagnosis and prognosis, as well as in developing the treatment plan. Guided endodontics exemplifies this digital technology by superimposing multiple 3D scans of intraoral tissues to create a virtual model. This model generates a template or guide for precise canal localisation. This review comprehensively explores guided techniques in endodontics, detailing their tools, procedural steps, clinical applications, advantages, disadvantages, and prospects, emphasising ongoing advancements in digital dentistry.

## INTRODUCTION

Blind endodontic treatment poses a considerable challenge due to the difficulty in accurately locating canals, which has routinely hindered the procedure's success. This problem of 'blindness' in accessing the right canals is now being addressed with the latest technologies and techniques. One of the modalities contributing to this evolution is the fabrication of surgical guides or templates that direct the bur to the canals, popularly known as guided endodontics. The minimally invasive approach is making an impact not only in restorative dentistry but also in endodontics, made possible by the integration of digitisation with dentistry. Surgical guides have been used for implant placement, reducing the risk of procedural errors.<sup>1</sup> Their use is being diversified, and digital workflows are being organised to incorporate techniques that make them suitable for endodontic use.<sup>2</sup>

Guided endodontics requires precise 3D data acquisition of both hard and soft tissues. The process involves three key steps: 1) Conducting a cone beam computed tomography (CBCT) scan to capture hard tissue details,

2) Performing an intraoral scan for detailed soft tissue mapping, and 3) Combining these scans to form a comprehensive virtual model. This model serves as a blueprint for digitally fabricating a surgical guide or template, which is then 3D printed to its life-like form.<sup>3</sup>

This is gaining popularity for treating severely calcified canals. It not only decreases chair-side time but also reduces the risk of perforation, which is increased many-fold during endodontic treatment of such teeth. Pulp canal calcification/obliteration is usually a sequela of trauma, but can also be caused by restorations, extensive caries, excessive orthodontic forces, or ageing, leading to canal narrowing and making them difficult to locate.<sup>4</sup> This is usually a routine radiographic finding, and treatment is required in symptomatic patients and in cases of apical periodontitis. Asymptomatic teeth without underlying pathology that are discoloured do not warrant endodontic treatment, and aesthetic rehabilitation of such teeth can be performed without endodontic intervention.<sup>3,5</sup>

Guided techniques can be static or dynamic, depending on whether a template is fabricated or real-time treatment



is performed with motion sensing based on the virtual guide.<sup>6</sup> Both approaches offer significant advantages, not only improving the prognosis of the treated tooth but also providing a more predictable and controlled treatment experience for both clinician and patient.<sup>3</sup>

### STATIC GUIDED ENDODONTICS:

Static guided endodontics relies on a pre-fabricated surgical guide to direct the dental bur. The workflow is characterised by pre-operative planning and the creation of a physical template (Figure 1).

#### Hard tissue assessment:

This is carried out using a CBCT radiograph, which digitally interprets the location and angulation of the tooth with respect to the alveolar bone three-dimensionally. Unlike conventional 2D radiographs, CBCT eliminates superimposition and distortion, offering an unparalleled view of complex anatomical structures. The root canals, their morphology, and any calcifications can be exquisitely appreciated in various CBCT sections (axial, sagittal, coronal, and oblique views).<sup>7</sup> This allows for the accurate definition of their precise locations within the tooth structure, including the pulp chamber, canal orifices, and the entire canal path. Advanced CBCT software allows for detailed measurements, identification of accessory canals, and assessment of root curvatures, all crucial for planning a minimally invasive access. The ability to visualise these structures before treatment is paramount in preventing iatrogenic errors and preserving tooth integrity.

#### Soft tissue assessment:

To assess the location of a tooth relative to intra-oral soft tissues, one can use either intra-oral optical scans or scan the impression recorded with a hydrophilic, rubber base material, such as Addition Silicone, known for its high dimensional stability. If intra-oral scanners are unavailable, a CBCT of the cast obtained from the intra-oral impression can be used. Its resolution, though, is less compared to intra-oral scanning.<sup>3,8</sup>

#### File format:

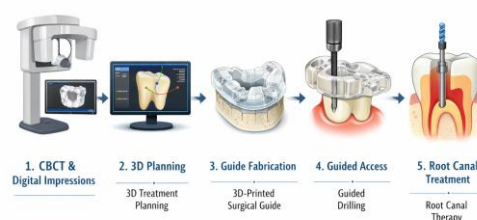
The files are preferred in the Standard Tessellation Language (STL) format, as the images are stored as point clouds, allowing them to be layered one over the other. This layering capability in STL format facilitates precise digital alignment, saving clinicians valuable chair-side

adjustment time. The CBCT files are in Digital Imaging and Communications in Medicine (DICOM) format, a universal standard for medical imaging. These DICOM files, containing volumetric data, must be converted into STL files for surface-based guide design. The optical scans are STL files and require no conversion.<sup>9</sup> The accuracy of this conversion and superimposition process is paramount for the ultimate precision of the surgical guide.

#### Virtual model construction:

The CBCT and optical scans are overlaid to create a virtual model. The CBCT files exhibit scatter, which compromises the accuracy of the workflow. The optical scans are free of scatter, and combining these two STL files yields a more accurate virtual model. The dimensions of the bur are measured using digital callipers, and a replica is formed, which is incorporated into the design of the template prepared over the virtual model.<sup>9</sup> Vents/irrigation ports are included in the guide, and the drill path is established 0.1-0.15 mm wider, facilitating efficient cooling of the trephine. This slight clearance not only aids in cooling but also reduces thermal damage to surrounding tissues, thereby enhancing biological safety and ensuring a more evidence-based approach to the procedure.<sup>10</sup>

Following the digital design phase, the customised template is fabricated using a 3D printer, typically with biocompatible resin. After printing, a precisely fitting metal sleeve is attached to the guide. This metal sleeve serves as the definitive channel, providing a rigid and accurate guide for the dental bur into the predetermined canal access path.<sup>7,9</sup>



**Figure 1: Static guided endodontic workflow**

### DYNAMIC NAVIGATION SYSTEM (DNS)

Static access has the drawback of the inability to change intraoperatively once the guide has been fabricated. This has been overcome by the introduction of a dynamic

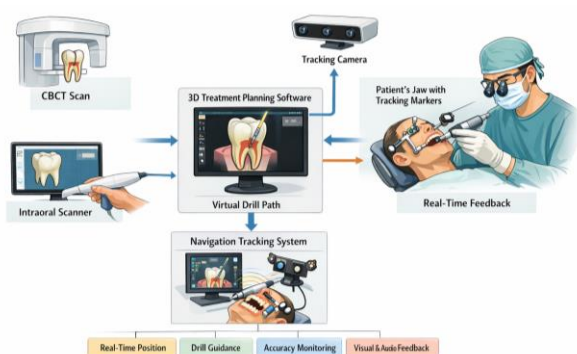


navigation system (DNS) that uses an optical positioning device to guide the handpiece along the predetermined path, along with motion tracking that aids real-time assessment of the procedure's progress (Figure 2).<sup>11</sup>

This requires a preoperative 3D CBCT scan, followed by planning the drill path virtually using software. For precise localisation and placement of the handpiece, the patient's jaw is mapped using a scanner.<sup>12</sup> This mapping not only facilitates accurate procedure guidance but also significantly reduces the need for multiple appointments, which is instrumental in enhancing patient convenience and aligning with practice management goals. The image obtained is matched and layered in a manner similar to the virtual model discussed earlier.

A stent is fabricated and placed with fiducial markers on the jaw, and a second CBCT scan is taken and layered onto the model. This step can now be eliminated with the introduction of a tracer tool that registers the fiducial markers on the jaw and calibrates to the virtual model, opening a window of corrections during the procedure and allowing accurate placement of the handpiece.<sup>12</sup> This was not possible with the prefabricated stent.

The handpiece and burs are digitally calibrated pre-operatively. The handpiece orientation is guided by the position indicators, and its movement is registered by the tracker, which transfers it to the virtual model created thereby, continuously tracing the progress of the procedure.<sup>11,13</sup> In case of any procedural error, it can be rectified there and then with the tracer.



**Figure 2: Dynamic navigation system workflow**

#### USES:

The guided access technique is mainly used for calcified teeth, but can also be used for treating cases with aberrant anatomy, especially with a dynamic navigation system.

It can be used in re-treatment cases for fibre post removal and for guiding osteotomy and root resection during endodontic surgery. This precision minimises surgical invasiveness, reduces collateral damage to surrounding tissues, and enhances the predictability of surgical outcomes.<sup>14</sup> The administration of local anaesthesia can be facilitated with DNS by real-time guidance, potentially improving the accuracy of needle placement, but further research is required.<sup>15</sup>

In cases of iatrogenic perforations, guided techniques could potentially be used to precisely locate the perforation site and guide the placement of restorative materials, offering a more predictable repair. Guided endodontics aligns with the principles of minimally invasive dentistry, preserving more coronal tooth structure and potentially improving the long-term prognosis of the tooth.

#### ADVANTAGES AND DISADVANTAGES:

A study conducted by Connert *et al.* (2019) revealed that substance loss in calcified teeth with traditional endodontic access is greater than with guided access, leading to preservation and conservation and reducing the risk of intra- and post-operative complications. According to Connert *et al.*, guided endodontics minimises the risk of perforation by approximately 30%. It reduces chair-side time, and treatment success is not dependent on the clinician's experience.<sup>16</sup> It offers a more predictable treatment with reduced chairside time.<sup>11</sup>

The guide is made of resin that can undergo shrinkage and warpage, which can interfere with its seating.<sup>17</sup> In case of improper seating, an adjustment is required on the inner surface to ensure proper placement. This technique cannot be used for curved canals or in cases of posterior teeth, where space is limited for the placement of the handpiece and the guide.<sup>18</sup>

DNS involves motion tracking; thus, it can be used in posterior regions with limited access. The placement of the handpiece as well as the operator is critical and defines the success of DNS treatment, according to a study conducted by Su *et al.* (2021), a mean angular deviation of  $2.8 \pm 2.6^\circ$  and a mean linear deviation of  $0.13 \pm 0.21$  mm coronally,  $0.46 \pm 0.4$  mm apically were observed in an *ex vivo* study.<sup>19</sup> Misalignment can lead to gouging, perforation, and missed canals. Hand-eye



coordination is extremely important, as continuous screen monitoring is required during treatment.<sup>11</sup> It has a steeper learning curve and requires more expertise for proper functioning than the static technique.

## FUTURE ASPECTS:

In the future, the template thickness is expected to be reduced, which will assist in placing the guide in the posterior region, occupying less space and allowing access for cavity preparation. Long-shank drills specifically for this purpose should be designed with a smaller diameter and calibrated.<sup>13</sup> Magnetic resonance imaging (MRI) has the potential to be utilised to record anatomic areas as a non-ionising alternative to CBCT to limit radiation exposure, but it is still under research.<sup>20</sup> While not yet mainstream for guided endodontics, optical coherence tomography (OCT) is a non-invasive, high-resolution imaging technique that provides cross-sectional images of biological tissues. It offers superior resolution for visualising superficial structures and could be used for real-time, in-situ imaging of the access cavity and canal orifices, aiding minimally invasive access and potentially reducing the need for extensive drilling.

Use of augmented reality (AR) with the DNS approach can provide an overhead display that facilitates treatment with less head mobility and continuous monitoring. AR technology can project the virtual drill path and real-time bur position directly onto the patient's anatomy or into the clinician's field of view via head-mounted displays. Future AR systems may offer even more sophisticated overlays, haptic feedback, and interactive guidance.<sup>21</sup>

Artificial intelligence (AI) can be used with DNS, though no supporting data is currently available. AI algorithms can rapidly and accurately segment anatomical structures (e.g., pulp chambers, root canals, calcifications) from CBCT images, reducing manual effort and potential for human error in the planning phase. Integrated AI could provide advanced real-time feedback during dynamic navigation, identifying subtle deviations from the planned trajectory and proactively alerting the clinician.<sup>22</sup>

The ultimate frontier in precision could involve robotic assistance. Robotic systems, guided by pre-planned digital blueprints and potentially integrated with AI and AR, could execute the drilling phase with unparalleled

accuracy and stability, further minimising human error and standardising outcomes.<sup>23</sup>

## CONCLUSIONS:

Guided endodontics is a clinician-friendly, minimally invasive modality for locating calcified canals, with a reduced risk of complications compared to the conventional approach. It has varied uses and advantages despite some limitations. The continuous advancements in digital dentistry promise to further refine and expand the capabilities of guided endodontics, solidifying its role as an indispensable tool for achieving predictable, efficient, and patient-centric root canal treatment in the future.

## References

1. Khanna SS, Balaji SM, Priyadarshani MB, Syed S, Syeda TT, Mohammed S. Surgical Guides in Implants: A Review. *Saudi Journal of Oral and Dental Research*. 2020.
2. Sesma N. The complete digital workflow in interdisciplinary dentistry. University of Pennsylvania. 2021.
3. Buchgreitz J, Buchgreitz M, Mortensen D, Bjørndal L. Guided access cavity preparation using cone-beam computed tomography and optical surface scans—an ex vivo study. *International endodontic journal*. 2016 Aug;49(8):790-5.
4. Long JD. Comparison of guided endodontic access with and without pin fixation in 3D printed teeth with simulated pulp canal obliteration (Doctoral dissertation).
5. McCabe PS, Dummer PM. Pulp canal obliteration: an endodontic diagnosis and treatment challenge. *International endodontic journal*. 2012 Feb;45(2):177-97.
6. Bun San Chong B, Manpreet Dhessi B, Makdissi J, RCR D. Computer-aided dynamic navigation: a novel method for guided endodontics. *Quintessence International*. 2019 Mar;50(3):196-202.
7. Krastl G, Zehnder MS, Connert T, Weiger R, Kühl S. Guided endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology. *Dental traumatology*. 2016 Jun;32(3):240-6.
8. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the



- current literature. *BMC Oral Health*. 2017 Dec 12;17(1):149.
9. Fonseca Tavares WL, Diniz Viana AC, de Carvalho Machado V, Feitosa Henriques LC, Ribeiro Sobrinho AP. Guided Endodontic Access of Calcified Anterior Teeth. *J Endod*. 2018 Jul;44(7):1195-1199.
  10. Lara-Mendes ST, Camila de Freitas MB, Machado VC, Santa-Rosa CC. A new approach for minimally invasive access to severely calcified anterior teeth using the guided endodontics technique. *Journal of Endodontics*. 2018 Oct 1;44(10):1578-82.
  11. Vasudevan A, Santosh SS, Selvakumar RJ, Sampath DT, Natanasabapathy V. Dynamic Navigation in Guided Endodontics—A Systematic Review. *European Endodontic Journal*. 2022 Jun 1;7(2):81.
  12. 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.
  13. Connert T, Weiger R, Krastl G. Present status and future directions—Guided endodontics. *International endodontic journal*. 2022 Oct;55:995-1002.
  14. Kulinkovych-Levchuk K, Pecci-Lloret MP, Castelo-Baz P, Pecci-Lloret MR, Oñate-Sánchez RE. Guided Endodontics: A Literature Review. *International Journal of Environmental Research and Public Health*. 2022 Oct 26;19(21):13900.
  15. Jain SD, Carrico CK, Bermanis I, Rehil S. Intraosseous anesthesia using dynamic navigation technology. *Journal of Endodontics*. 2020 Dec 1;46(12):1894-900.
  16. Connert T, Krug R, Eggmann F, et al. Guided Endodontics versus Conventional Access Cavity Preparation: A Comparative Study on Substance Loss Using 3-dimensional-printed Teeth. *J Endod*. 2019;45(3):327–31.
  17. Nestler N, Wesemann C, Spies BC, Beuer F, Bumann A. Dimensional accuracy of extrusion- and photopolymerization-based 3D printers: In vitro study comparing printed casts. *The Journal of Prosthetic Dentistry*. 2021 Jan 1;125(1):103-10.
  18. Pujol ML, Vidal C, Mercadé M, Muñoz M, Ortolani-Seltenerich S. Guided endodontics for managing severely calcified canals. *Journal of Endodontics*. 2021 Feb 1;47(2):315-21.
  19. Su Y, Chen C, Lin C, Lee H, Chen K, Lin Y, Chuang F. Guided endodontics: accuracy of access cavity preparation and discrimination of angular and linear deviation on canal accessing ability—an ex vivo study. *BMC Oral Health*. 2021 Dec;21(1):1-9.
  20. Leontiev W, Bieri O, Madörin P, Dagassan-Berndt D, Kühl S, Krastl G, Krug R, Weiger R, Connert T. Suitability of magnetic resonance imaging for guided endodontics: proof of principle. *Journal of Endodontics*. 2021 Jun 1;47(6):954-60.
  21. Song T, Yang C, Dianat O, Azimi E. Endodontic guided treatment using augmented reality on a head-mounted display system. *Healthcare Technology Letters*. 2018 Oct;5(5):201-8.
  22. Setzer FC, Li J, Khan AA. The use of artificial intelligence in endodontics. *Journal of dental research*. 2024 Aug;103(9):853-62.
  23. Farronato M, Torres A, Pedano MS, Jacobs R. Novel method for augmented reality guided endodontics: an in vitro study. *Journal of dentistry*. 2023 May 1;132:104476.