

A Systematic Review of Research on Guided Access Cavity Preparation Endodontic Treatment: Dentin Preservation Perspectives

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Purpose: Guided access cavity preparation (GACP) is an endodontic procedure utilizing stents, guide sleeves, or dynamic guides to facilitate the proper formation of access cavities. This paper aims to evaluate the significance of research on guided access cavity preparation in endodontic treatment concerning dentin preservation. In the context of dentin preservation, this paper provides a thorough scoping review of a variety of methodologies for evaluating the accuracy of guided access cavity preparation.

Materials and Methods: Article searches were conducted using the keywords "Guide Access Cavity Preparation" AND "Static Guide OR 3D Printing Template" AND "Dynamic Guide through digital databases including PubMed, Scopus, Cochrane Library, Science Direct, and Google Scholar. Research articles published in English within the past five years (2019-2024) and in accordance with the PCC (Population, Concept, and Context) framework were also included in the study. Articles from the meta-analysis or systematic review study type, those that were not accessible in full text or in a paid format, and those that did not assess the use of guided endodontics in endodontic surgery were excluded. This scoping review adheres to the Preferred Reporting Items for Systematic Reviews without Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) criteria.

Results: A total of 12 articles were reviewed, encompassing various locations, designs, type, and samples, which demonstrated the use of guided access cavity preparation has significant clinical applications and can provide accurate results in endodontic therapy.

Conclusion: Article searches were conducted using the keywords "Guide Access Cavity Preparation" AND "Static Guide OR 3D Printing Template" AND "Dynamic Guide through digital databases including PubMed, Scopus, Cochrane Library, Science Direct, and Google Scholar. Research articles published in English within the past five years (2019–2024) and in accordance with the PCC (Population, Concept, and Context) framework were also included in the study. Articles from the meta-analysis or systematic review study type, those that were not accessible in full text or in a paid format, and those that did not assess the use of guided endodontics in endodontic surgery were excluded. This scoping review adheres to the Preferred Reporting Items for Systematic Reviews without Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) criteria. Studies show that advanced technologies in guided access cavity preparation endodontic treatment can improve dentin preservation, improve accuracy and predictability, particularly for root canal anomalies and difficult teeth, but clinicians must consider limitations and clinical applications. Clinicians must evaluate the limitations and clinical applications of guided endodontic access prior to its implementation.

Keywords: guided endodontic access, GEA, guided access cavity preparation, GACP, static guided endodontic access, SGEA, dynamic guide endodontic access, DGEA, preservation dentin

Introduction

Guided access cavity preparation (GACP) is a technique used in endodontic treatment that involves the use of stents or guide sleeves or dynamic guide to assist in the accurate and precise preparation of access cavities.^{1,2} The guided access

cavity preparation has gained attention and popularity in recent years due to advancements in cone-beam computed tomography and three-dimensional rapid prototyping manufacturing technology. This technique allows for more conservative access cavity preparation, decreased chair time, and reduced risk of iatrogenic damage.^{3,4} Preserving tooth structure is a fundamental principle in minimally invasive endodontics.^{5–12}

Minimally invasive endodontic access opening preparation techniques using guided access have shown promising outcomes in various clinical scenarios. These include cases of pulp canal calcification, dens evaginatus, anomalous teeth. The guided endodontics technique has been compared to conventional methods using models in numerous pioneering studies.^{2,13–19} Successful applications of guided endodontics in clinical practice, such as cavity preparation, root canal localization, have been demonstrated in recent clinical case reports.^{3,20,21}

Preserving tooth structure is now the main goal of endodontic, restorative, and contemporary dentistry techniques.^{2,13–19} Minimally invasive endodontics maximizes the preservation of natural tooth structure by reducing the amount of preparation required for the access cavity, the prepared apical size, and the taper of prepared canals.²² Cone beam computed tomography, operating microscopes, and ultrasonic instruments are examples of sophisticated endodontic instruments that have made this therapeutic paradigm change possible. Aiming to create access points that maintain as much healthy tooth structure as feasible, the term “minimally invasive endodontic access cavities” refers to this process.^{22,23} In this scoping review, we aim to examine the current research on guided access cavity preparation techniques that prioritize the preservation of dentin aspects, clinical applications, accuracy, and limitations of guided access cavity preparation in achieving minimally invasive endodontic outcomes.

Materials and Methods

Research Question

The research question formulated using the PCC (Population, Concept, and Context) framework was: A comparative evaluation of guided endodontic (static and dynamic navigation systems) versus freehand in the preparation of endodontic access cavities, focusing on the preservation of tooth structure in permanent human teeth.

Search Strategy

The study focused on access cavity endodontic treatment of anterior or posterior teeth using guided endodontic techniques. Articles were screened following PRISMA-ScR guidelines. (Figure 1). Independent authors conducted a scoping review search to identify all articles published up to the end of June 2024 in three databases: PubMed, Cochrane Library, Science Direct, and Google Scholar.

Studies Selection

The study utilized digital databases and Boolean Operators to conduct a comprehensive literature search on guided endodontic access cavity preparation, focusing on its accuracy compared to conventional techniques. Key terms used included “Guide Access Cavity Preparation”, “Static Guide”, “3D Printing Template”, and “Dynamic Guide”, based on limited discourse and understanding of the technique. The study analyzed research published between 2019-Juni 2024 on access cavity preparation non-surgical root canal therapy for anterior and posterior teeth. Post-removal, retreatment, surgical-guided endodontic procedures, gray literature, reviews, case reports, and commentaries or narratives were also excluded.

Data Extraction

The articles were sifted for duplicates and relevance, and then analyzed using established criteria, with inclusion in data extraction Table 1 limited to individuals meeting specified criteria. The Joanna Briggs Institute’s guidelines were employed to evaluate the methodological quality of the selected articles using a self-designed criteria checklist.²⁴ Each full-text article was evaluated for a variety of bias domains, such as angulation, accuracy, time consumed, sample size calculation, randomization, and image acquisition using CBCT. The articles were categorized into low, moderate, and high levels of evidence by the scoring system. An article was classified as having a “low” risk of bias if all domains were

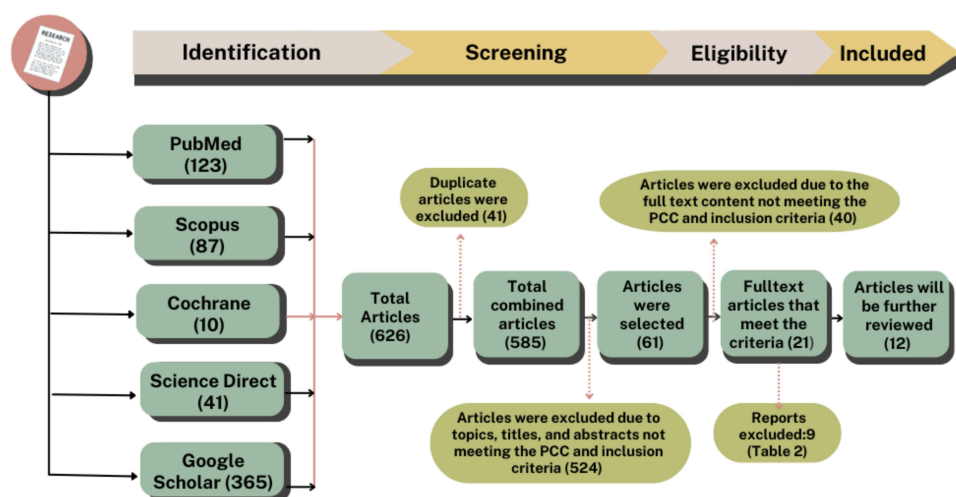


Figure 1 PRISMA Flow Diagram for the Selection of Studies in the Scoping Review.

Notes: PRISMA Flow Diagram depicting the study selection procedure for the systematic review. It specifies the quantity of records identified by database searches and alternative methods, the screening procedure, and the number of studies incorporated in the review.

rated low, and a “high” risk was ascribed if any domain was rated high. “Unclear” articles had at least one domain that was rated as such. Disagreements among authors were resolved through consultation with a third reviewer.

Results

A literature search was conducted using keywords on four databases, resulting in a total of 626 articles. As a result, 12 papers were selected for further evaluation, whereas 614 articles were discarded since they did not meet the PCC and inclusion criteria. The article screening method is illustrated in [Figure 1](#) and [Table 2](#) of the research procedure steps in the execution diagram, utilizing the PRISMA-ScR framework. The twelve papers that were evaluated were then recorded in a data extraction table, specifically referred to as [Table 1](#). The data extraction table provides a concise summary of the data, encompassing details such as the names of the researchers, the years of the studies, the titles of the research, the places where the studies took place, the designs of the studies, the samples used, and the conclusions of the research.

Table 1 presents the main discoveries derived from twelve research publications that focus on guided access cavity preparation. Sample types in these research articles are used as varied: artificial teeth were used in 8 articles (67%), and extracted teeth were used in 4 articles (33%), represented in [Table 1](#). Different guided endodontic access cavity preparations were used: static guide was used in 8 articles (31%), dynamic guide was used in 6 articles (23%), and freehand was used in 12 article (46%) represented in [Table 1](#). Different types of research on guided access cavity preparations were used: in vitro was used in 10 articles (83%) and ex vivo was used in 2 articles (17%), represented in [Table 1](#). Different types of sample root canals were used: normal tooth was used in 6 article (50%), and pulp canal obliteration or calcification was used in 6 articles (50%). The operators in these researches had a range of competence skill levels, including undergraduate general dentist was used in 1 article (8%), fresh graduate general dentist was used in 1 article (8%), general dentist was used in 5 articles (38%), and senior specialist in endodontic was used in 6 articles (46%) represented in [Table 1](#).

Result evaluation quality of the selected articles included among the 12 studies analyzed, two study incorporated all three techniques,^{28,36} whereas the remaining studies compared Guided Endodontic Access (SGEA or/and DGEA), compared FHA (Freehand Access) for access cavity preparation endodontic treatment.^{25–27,29–35} All studies assessed image acquisition using CBCT, and SGEA, after which the dynamic navigation system was employed for real-time access cavity preparation.^{25–36} The loss of tooth substance was comparatively evaluated across four studies that assessed angulation.^{27–29,36} Five studies analyzed accuracy and time taken, demonstrating that guided endodontic exhibited increased accuracy, reduced angulation variations, and shorter time requirements compared to the free-hand approach represented in [Table 1](#).^{26,27,29,32,36}

Table 1 Data Extraction on Experimental Studies

No	Author	Research Type	Sample Type	Sample	Root Canal Type	Guide Type (Method)	Operator	Impression	CBCT	Voxel/Exposing Parameters	Software	3D Printed	Virtual Bur Diameter	Drill	Template/ Sleeve Characteristics	Mean Linear Deviation/ mm	Mean Angular Deviation/ °	Substance Loss/mm ³	Success Rate/ %
1	Connert et al (2019) ²⁵	In Vitro	Artificial Teeth	48 printed incisors with calcified canals	PCO	SGE, FH	Specialist in endodontics (9 years); Dentist (3 years); new dental school graduate.	Dental Wings Intraoral Scanner; Dental Wings Inc, Montreal, Canada	Morita Accutomo 80; J Morita Manufacturing Corp, Kyoto, Japan	125 mm	coDiagnostiX software (Version 9.2, Dental Wings Inc)	Objet Eden260 V, material: MED410; Stratasys Ltd	0.85 mm (Gebr Brasseler GmbH & Co KG, Lemgo, Germany)	A cylindrical diamond bur with rounded edges (837 KR; Intensiv SA, Switzerland); long pulp burs ("MEüller" bur, Gebr Brasseler GmbH & Co KG) and/or an ultrasonic device (P Max Newtron XS; Acteon, D Eusseldorf, Germany) with a size 25 IRRI K file (VDW GmbH, Munich, Germany).	Custom metallic sleeves (steco-system-technik GmbH & Co KG, Hamburg, Germany)	N/A	N/A	9.849.9*	91.741.7*
2	Jain et al (2020) ²⁶	In vitro	Artificial Teeth	84 printed teeth (calcified canals); 78 on maxillary teeth and 60 on mandibular teeth* (36 were anterior teeth, 30 were from premolars and 72 were from molars)	PCO	DGE (Navident)	N/A (Single Operator)	Resident (2nd year)	CS 8100 3-D; Carestream Health Inc, Rochester, NY	75 mm	Navident (ClaroNav, Toronto, Ontario, Canada) implant/access planning software	N/A	1.0-mm diameter and depths ranging from 9.5–21 mm	Precision micro endodontic (tip diameter 5 0.28 mm) high-speed access burs (Endoguide EG3; SSWWhite, Lakewood, NJ); surgical-length (tip diameter 5 0.21 mm) tapered diamond carbide burs (859 FGSL; Komet/USA, Rockhill, SC)	N/A	2D deviation - entry (mm) anterior (base) 1.0 premolar (base) 1.2 molar (base) 1.0 3D deviation - canal orifice (mm) anterior (tip) 1.3 premolar (tip) 1.1 molar (tip) 1.4	Anterior 1.53 premolar 1.38 molar 1.89	N/A	100

3	Gambarini et al (2020) ²⁷	In Vitro	Artificial Teeth	Twenty radiopaque, artificial teeth replicas (TrueTooth 3-001, USA); 132 artificial teeth in silicon bases	Normal	DGE (Navident) FH	N/A (the same skilled operator)	N/A	OP-Maxio 300, Instrumentarium-KaVo, Biberach, Germany	85 µm	Navident dynamic navigation system (ClaroNav, Toronto, Ontario, Canada)	N/A	N/A	A small round I4 bur (SSWhite, Lakewood, NJ, USA), a precision micro endodontic bur (EndoGuide EG1s, SSWhite) with a 0.33 mm tip and 1 mm; 10,000 rpm using a red high-speed contrangle (ExpertMatic E25L, KaVo, Biberach, Germany).	N/A	0.340.88 ^a	4.821.2 ^a	N/A	N/A
4	Zubizarreta-Macho et al (2020) ²⁸	In Vitro	Extracted Teeth	30 single rooted anterior teeth in epoxy resin models	Normal	SGEDGE (Navident) FH	N/A	EVO, Ceratonic, Protechno, Girona, Spain NemoScan [®] , Nemotec, Madrid, Spain	WhiteFox, Aceón Médico-Dental Ibérica S.A.U.- Satelec, Merignac, France	105.0 kilovolt peak, 8.0 milliamperes, 7.20 s, and a field of view of 15x13 mm.	NemoScan [®] , Nemotec, Madrid, Spain Navident, ClaroNav	ProJet [®] 6000, 3D Systems [®] , Rock Hill, SC, USA	A diameter of 1.2 mm, of 14 mm, and a drilling depth of 11 mm	The incisal bur with a diameter of 1.2 mm, 14 mm, A diamond bur with a diameter of 1.2 mm, 14 mm, and a 11 mm was used (Ref. 882314012, Komet Medical, Lemgo, Germany). Working length of 11 mm was used (Ref. 882314012, Komet Medical.	Navident, Navident, ClaroNav Resin sleeve	Base 7.44 tip 7.13 base 3.14 tip 2.48 base 4.03 ^{16a} tip 2.43 ^{16a}			
5	Dianat et al (2020) ²⁹	In Vitro	Extracted Teeth	60 single-rooted teeth with calcified canals in cadaver jaws	PCO	DGE (X-guide)FH	N/A (2 operators with different levels of experience)	N/A	(CS 9300; Carestream LLC, Atlanta, GA)	0.090-mm resolution.	The X-Guide system (X-Nav Technologies, LLC)	N/A	N/A	A size #1 (08 mm) Munce bur (CJM Engineering Inc, Ojai, CA) on a slow-speed handpiece at 5000 RPM.	N/A	Mesial/distal 0.12 buccal/lingual 0.19 mesial/distal 0.31 ^a buccal/lingual 0.81 ^a	2.397.25 ^a	N/A	96.683.3

(Continued)

Table 1 (Continued).

No	Author	Research Type	Sample Type	Sample	Root Canal Type	Guide Type (Method)	Operator	Impression	CBCT	Voxel/Exposing Parameters	Software	3D Printed	Virtual Bur Diameter	Drill	Template/ Sleeve Characteristics	Mean Linear Deviation/ mm	Mean Angular Deviation/ °	Substance Loss/mm ³	Success Rate/ %
6	Loureiro et al (2020) ³⁰	Ex vivo study	Extracted Teeth	20 mandibular incisors and upper molars	Normal	SGEFH	Specialized in endodontics (over 15 years)	N/A	PreXion 3D (San Mateo, CA, USA); 3Shape Dental SystemTM1 apparatus (Copenhagen, Denmark).	FOV: 56.00 mm x 56.00 mm, voxel 0.1 mm. The voltage was 90 kVp, and 4 mA, with an exposure time of 33.5 s.	Blue Sky Plan software (Blue Sky Bio, United Kingdom)	3D printer (Straumann® CAR ES® P30).	NeoSurg Pro engine (Neodent, Curitiba, PR, Brazil); 800 rpm and a torque of 40 N.cm; length were guided by 1.5-mm internal diameter metal washers (Guided Surgery - Neodent, Curitiba, PR, Brazil).	Spherical diamond bur n. 1011 and conical bur n. 2200 (KG Sorensen, SP, Brazil); Rounded diamond tips # 1013 (KG Sorensen, SP, Brazil), A trapezoidal metal washers Endo Z (Dentsply / Maillefer, Ballaigues, Switzerland).	Metalic sleeve	N/A	N/A	Incisor 26.5 molar 45.7 incisor 31.7 molar 62.5*	N/A
7	Kosunov et al (2021) ³¹	In Vitro	Artificial Teeth	Typodont teeth with 30 canals in acrylic resin model (incisors, premolars, molars) 11, 14, 17 (ANA-4 ZPUR, frasco GmbH, Germany).	Normal	SGEFH	Dentist (experience)	N/A	Galleos Comfort Plus, Dentsply Sirona; York, PA, USA	Field of view: sphere with a diameter of 15.4 cm, 12 bit; scan time: 14 sec, 357 images; voxel size: 0.25×0.25 × 0.25.	coDiagnostix software (Dental Wings; Montreal, Canada).	N/A	N/A	A cylindrical diamond bur with rounded edges (Kometedental, Gebr. Brasseler GmbH, Lemgo, Germany)	Steco GmbH; Hamburg, Germany	N/A	N/A	Incisor 10.3 premolar 29.3 molar 51.8 incisor 16.1* premolar 44.2* molar 99.3*	N/A
8	Connert et al (2021) ³²	In vitro	Artificial Teeth	72 typodont teeth on models	Normal	DGE (DENA CAM)FH	2 Dentist (2 and 12 years)	TRIOS 3; 3Shape A/S, Copenhagen, Denmark	Accutomo 170; Morita Manufacturing Corp, Kyoto, Japan	Voxel size of 125 mm, 90 kV, 6 mA, and a field of view(FOV)of 616cm.	Planning software coDiagnostiX, DENATRAX, Minivident AG	Objet Eden 260 V, Material: MED410; Surtracsys Ltd, Minneapolis, MN	N/A	Standard cylindrical diamond bur with a diameter of 1.0 mm (Intensiv SA, Montagnola, Switzerland)	Incorporated sleeve	N/A	N/A	10.5297 [^]	97.297.2
9	Hildebrand et al (2023) ³³	Ex vivo	Extracted Teeth	108 human extracted calcified teeth (36 canines and 72 incisors, 36 maxillary and 72 mandibular teeth)	PCO	SGE	Specialized in endodontics and dentist	TRIOS 3 Basic, 3Shape A/S, Copenhagen, Denmark	Accutomo 170; Morita Manufacturing Corp, Kyoto, Japan	80KV and 6 mA using a voxel size of 250 µm and a field of view (FOV) of 10×10 cm.	coDiagnostiX, Dental Wings Inc., Montreal, Canada	98.5 mm; Yamahachi Dental, Gamagori, Japan	A standard cylindrical diamond bur with round edges and a diameter of 1.0 mm (837 KR; Intensiv SA, Montagnola, Switzerland)	A carbide drill with a diameter of 1.0 mm (ATEC Endoseal, Steco-System-Technik).	StecoGuide Endo-Sleeve; Steco-System-Technik, Hamburg, Germany	N/A	N/A	CONV (specialist) 22.8 (15.9–29.6) GE (general dentist) 22.6 (17.6–27.5)	100%

10	Vasudevan et al (2023) ³⁴	In vitro	Artificial Teeth	Forty-two resin incisor teeth	PCO	FH, SGE	Senior endodontist (SE), postgraduate (PG), and undergraduate (UG)	N/A	CBCT scans (Planmeca, Finland)	Voxel size: 75 µm; FOV: 4 cm × 5 cm	Mimics 2.0 Software. Geomagic Freeform Plus Software	Formlabs Inc., Somerville, MA, USA	Bur (0.8 mm) corused ponded to the bur head size (0.7 mm).	Access cavities were initiated with high-speed 1/2 size round diamond burs at the center of the incisal edge. After 3–4 mm of penetration, Gates Glidden drills #1, #2 (Mani, Inc.) and long-neck carbide bur (Dentsply Sirona, USA)	Resin sleeve	N/A	N/A	IEA 66.87 ±12.54** SGEA 19.39 ±2.76** SE; PG –6.44; UG –17.96* PG; UG –11.51	100%
11	El hakim et al (2023) ³⁵	In vitro	Artificial Teeth	Four types of acrylic teeth (tooth #11, 15, 16, 46, A22AN-200, Nissin Dental Products Inc., Kyoto, Japan)	Normal	SGE	Dentist (fresh graduate); dentist (5 year experience endodontic)	TRIOS3 wireless pod intraoral scanner with insane and AI scan modes activated (3Shape A/S, Copenhagen, Denmark)	Alphard 3030, Asahi Roengens Ind., Co. Ltd, Kyoto, Japan	A 50mm diameter spherical field of view 80kV X-ray source at 8mA, a scan time of 17s and a voxel size of 0.1 mm3,	Exocad GmbH, Darmstadt, Germany	NextDent [®] 5100, NextDent B.V, Soesterberg, Netherlands	A cylindrical end cutting only bur (REF 80631415 0524016, Hager & Meisinger GmbH, Neuss, Germany)	The preparation was enlarged using a cylindrical diamond flat end bur (REF 80631410 8524016, Hager & Meisinger GmbH)	Resin sleeve	N/A	N/A	TradA COPI: 69.3 + 9.0OP2: 73.9‡ 11.7Cons ACOPI: 79.1‡ 15.0OP2: 68.6‡ 75.6‡ 13.7Guid ACOPI: 71.9 + 17.0OP2: 74.6 ‡15.9	TradA COPI: 65.2 + 5.8OP2: 75.8 +5.9 Cons ACOPI: 58.0‡ 10.3OP2: 68.6‡ 75.5GuidA COPI: 83.3 + 7.0OP2: 79.7‡5.2
12	Huth et al (2024) ³⁶	In vitro	Artificial Teeth	36 3D printed teeth (1) 13; 1 root canal obliterated till the middle apical third, (2) 37 with an obliterated MB2 root canal to be localized (3) 36 with a pulp chamber containing pulp stones with the D root canal to be found, (4) 43 having a second lingual canal.	PCO	SGEDGE (Denacam) FH	Dentist (5 years include endodontic)	Activiy 885 Mark 2, Pluradent GmbH and Co. KG, Offenbach, Germany;stl dataset	CBCT Carestream CS9300, Carestream Dental, Atlanta, USA	Voxel size 0.090 mm	Denacam system (mininavident AG, Liestal, Switzerland). coDi-agnostiX, Dental Wings INC, Montreal, Canada)	Stereolithographic printer (rapidshape D20+, Rapid Shape GmbH, Heimsheim, Germany).	Steco-system-technik GmbH & Co. KG, Ham-burg, Germany; diameter 1 mm, working length 21 mm)	Virtual endodontic bur (Spiralbur Endo, Ref.: O.27.28. B044.051	SAC (Sleeve Guided Endo Ref.: M.27.28, D100L5).	Freehand 9.53 ± 6.36 Dynamic 2.82 ± 1.8 Static 1.12 ± 0.85	Base offset 3D (mm) Freehand 1.85 ± 0.89 Dynamic 1.62 ± 0.7 Static 0.77 ± 0.37 Tipoffset 3D (mm) Freehand 1.52 ± 0.90 Dynamic 1.65 ± 0.79 Static 0.86 ± 0.38	Freehand 31.90 ± 19.78 Dynamic 9.43 ± 9.02 Static 17.60 ± 10.66	Freehand 93.7 Dynamic 95.8 Static 97.9

Notes: *P < 0.05 as compared to SGE, ^P < 0.05 as compared to DGE.

Abbreviations: SGE, Static Guided Endodontics; DGE, Dynamic Guided Endodontics; FH, Freehand; MTA, Mineral Trioxide Aggregate; CEJ, Cementoenamel Junction; PCO, Pulp Canal Obliteration; MB2, second mesio buccal; D, Distal.

Table 2 Excluded Studies with Reason for Exclusion

NO	Author (Year)	Reason For Exclusion
1	Torres et al (2023a) ³⁷	Evaluate the accuracy of sleeveless guided endodontics for root canal treatment of severe pulp canal obliteration (PCO) in 3D printed jaws-no comparator group GE/FH
2	Chaves et al (2023) ³	Evaluated the precision of a simplified workflow using only preoperative cone-beam computed tomographic (CBCT) scans to gain guided access to root canals of extracted mandibular molars; no comparator group GE/FH
3	Haarmann et al (2023) ³⁸	Determine the accuracy of template-based guided endodontics for access cavity preparation and root canal detection in posterior teeth; no comparator group GE/FH
4	Kamburoglu et al (2023) ⁴	Evaluate the accuracy of guides prepared using CBCT images on 3D-printed teeth with stereolithography (SLA) using three different materials and two different layer thicknesses; no comparator group GE/FH
5	Torres et al (2023b) ³⁹	Validate the use of a post-operative intraoral scan (IOS) versus Cone Beam Computed Tomography (CBCT), gold standard, on its ability to measure the accuracy of guided endodontics, and (2) present clinical data on the accuracy of guided endodontics: no comparator group GE/FH
6	Christofzik et al (2021) ⁴⁰	Compared endodontic access cavities prepared by operators of different experience levels (students, general-practitioners and specialists); no comparator group GE/FH
7	Koch et al (2022) ⁴¹	Evaluate the accuracy and precision of desktop 3D printers when fabricating stents for guided endodontics.: no comparator group GE/FH
8	Su et al (2021) ¹	Evaluate the accuracy of three dimensional (3D)-printed endodontic guides for access cavity preparation in different types of teeth: no comparator group GE/FH
9	Sameer Jain et al (2020b) ⁴²	Present a novel dynamic navigation method to attain minimally invasive access cavity preparations and to evaluate its 3-dimensional (3D) accuracy in locating highly difficult simulated calcified canals among maxillary and mandibular teeth.: no comparator group GE/FH

Six studies compared SGEA and the freehand technique, showing that SGEA had greater accuracy and less tooth substance loss related to angulation variations.^{25,30,31,33–35} Four studies compared DGEA and FHA, with SGEA again demonstrating superior accuracy and minimized tooth substance loss compared to the freehand technique.^{26,27,29,32} In comparison to both static-guided endodontics and the freehand technique, DGEA demonstrated better accuracy and reduced tooth substance loss in relation to angulation variations in two studies.^{28,36}

The evaluation of randomisation, sample size calculation, image acquisition via CBCT, angulation, accuracy, and time taken was performed in the full-text articles to assess the risk of bias. The scoring of the level of evidence for the five included articles was tabulated, with the overall risk of bias assessment summarized in Figures 2 and 3. Three articles exhibited a low risk of bias, while 9 articles demonstrated a high risk of bias due to the lack of evaluation of key parameters.^{25,26,28,31–35} The study by Connert et al (2019) did not report data on randomisation, sample size calculation, angulation, accuracy, and time taken.²⁵ Sameer D Jain et al (2020) had unclear sample size calculation and did not assess angulation.²⁶ Zubizarreta-Macho et al (2020) conducted a comparative evaluation but lacked information on sample size calculation, accuracy, and time taken.²⁸ Loureiro et al (2020) did not mention key domains of randomisation, sample size calculation, angulation, and accuracy.³⁰ Kostunov et al (2020) also omitted data on sample size calculation, angulation, and time taken.³¹ Connert et al (2021) failed to report on randomisation, sample size calculation, and angulation.³² Hildebrand et al (2023) and Vasudevan et al (2023) lacked clarity in randomisation and did not assess angulation and accuracy.^{33,34} El Hakim et al (2023) did not mention data on randomisation, sample size calculation, angulation, and time taken. Consequently, these nine studies were categorized as having a high risk of bias.³⁵

Discussion

The conventional approach to access cavity preparation compromises the structural integrity and stability of the tooth, with a typical reduction of 63% in relative cuspal stiffness due to the loss of marginal ridge integrity.^{28,43} Preserving enamel and dentin during this process enhances the tooth's biomechanical response to occlusal loading, while increased coronal wear leads to higher stress concentrations at the cervical region. The pericervical dentin is subjected to increased stress as the access cavity is expanded. The tooth's internal morphology, deformability, and fracture resistance are

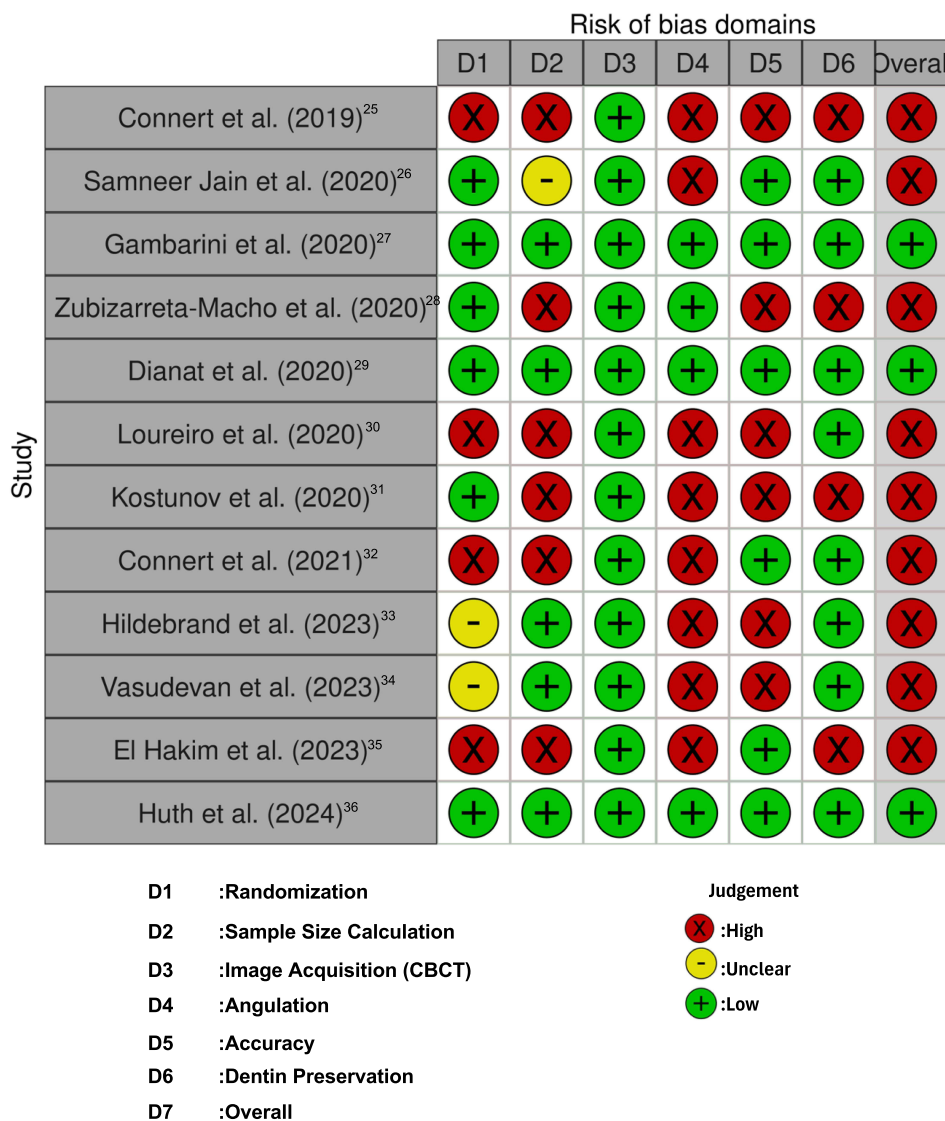


Figure 2 Risk of bias assessment “Traffic Light” summary plot.

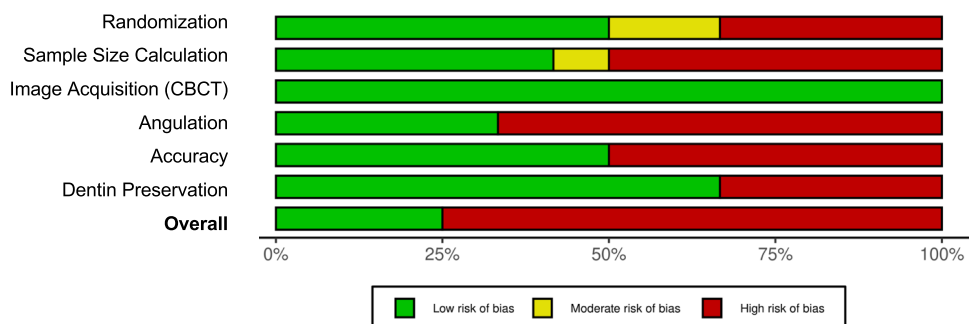


Figure 3 Risk of bias assessment graph.

compromised as a result of the excessive removal of this dentin during endodontic therapy.^{44,45} The disproportionate loss of tooth structure can be mitigated through the use of magnification; however, cavities accessible by free-hand are frequently encountered.^{42,46–49}

Guided Access Cavity Preparation (GACP) is a method that efficiently controls cavity preparations, reducing dentin loss, prioritizing the preservation of healthy tooth structure, and ensuring excellent access while retaining biomechanical integrity.^{1,15,25} It corresponds with contemporary dentistry's minimum invasive techniques.^{5,23,50} Guided access cavity preparation is a method in endodontic treatment that offers precise and accurate preparation, particularly in complex cases like calcified canals or anatomical variations. It contributes to more conservative dentistry by using 3D CBCT images to optimize root canal identification.^{13,14,16,19,30,51–53} Advancements in rapid prototyping manufacturing technology and cone-beam computed tomography have made guided endodontics possible. Two methodologies, SGE and DGEA, have shown significant interest in improving precision, reducing surgery time, and patient satisfaction.^{2,19,36,54,55} Traditional methods were effective in locating canals in only 41.7% of cases in 2019, while guided approaches were successful in 91.7%.²⁵ 3D printing technology can generate models with internal root anatomy, enhancing precision and minimizing iatrogenic errors.^{2,19,25,53,54,56,57}

SGEA that employs a preset access drill route derived from cone beam computed tomography (CBCT) and transmitted to a rigid template has been developed as a result of advancements in 3D printing and surface scanning. This CBCT-based splint guidance safeguards healthy tooth structure and minimizes iatrogenic errors. A printed template with sleeves is improved by precise pre-operative planning using 3D CBCT images, which enables the precise localization of the root canal. Connert et al (2019) reported an average substance loss of 9.8 mm and a missed canal prevalence of 8.3%. Conventional access cavity preparation resulted in five times more substance loss than static guided preparation. Additionally, 3D printed root canals were accurately identified in 91.7% of guided endodontic cases, as opposed to 41.7% of normal cases. Nevertheless, the time and expenses that are associated with this process increase.²⁵

Volumetric tooth substance loss during dental operations has been greatly decreased since the advent of DGEA. DGEA reduces iatrogenic mistakes, improves visualization of dental tissues while maintaining tooth structure, and enables real-time modifications to the access cavity direction. DNS improves accuracy and dependability over the FHA approach by exhibiting fewer linear and angular deviations as well as a small decrease in dentinal thickness.^{26, 29, 62, 63} huth (2024) claims that there was a difference in angle deviation between the three methods ($p < 0.0001$). The FHA technique had the largest deviation ($9.53 \pm 6.36^\circ$), followed by DGEA ($2.82 \pm 1.8^\circ$). SGEA was the most accurate ($1.12 \pm 0.85^\circ$). The operating method had the strongest effect on accuracy ($\eta P^2 = 0.524$), followed by tooth type** ($\eta P^2 = 0.364$) and operator skill ($\eta P^2 = 0.08$). There was no significant difference in bur base and tip localization among the three techniques. In terms of tooth substance loss, the FHA method caused the most damage ($p < 0.001$), while DGEA preserved the most ($p < 0.0001$). For operating time (time taken), freehand was the quickest, followed by SGEA, with DGEA taking the longest.^{28,36,58}

Zehnder et al (2016) reported an average angular deviation of 1.81° . Using a 1.5 mm implant bur, they observed coronal deviations between 0.16–0.21 mm and apical deviations from 0.17–0.47 mm. In the maxillary teeth, FHA cavities led to double the material loss and showed poorer trajectory accuracy compared to DGE.⁵⁹ Buchgreitz et al (2019) found that optimal trajectory was achieved in 75% of dynamically navigated cases, compared to 40% in static guided cases. DGE further reduced the risk of perforation, successfully identifying root canals in 96.6% of cases without perforation. Additionally, Dianat et al (2020) noted that DGE improved the efficiency of access cavity preparation, completing it in an average of 4 minutes (maximum of 7 minutes), while the FHA group required 7 to 19 minutes.²⁹

The results show that GEA techniques are more accurate and protect more tooth material than FHA methods. Although freehand is faster, it is less precise and causes more tooth damage. This suggests that GEA[®] is better for procedures where accuracy is important.

Limitation

The study highlights the clinical benefits of guided endodontics. It helps locate root canals more precisely and reduces damage to the tooth structure. However, the guided techniques take longer than freehand. The study has some limitations, such as using an in vitro model, limited tooth variety, and possible lack of training with the DGE. These factors may affect the results, and more research is needed to confirm the findings. This study shows that DGE is more accurate and causes less tooth damage than freehand methods. While FHA is faster, GEA techniques are better for preserving tooth

material. Further clinical studies are needed to confirm these results in real-world settings. Using 3D-printed teeth for research seems useful and could improve future studies.^{36,58,60,61}

The accuracy of guided access cavity preparation has been validated through pre-clinical studies, demonstrating its reliability compared to traditional methods. Gambarini et al (2020) reported that the DGEA exhibited significantly greater precision than FHA techniques. Specifically, the DGEA group achieved a mean angulation deviation of 4.8°, whereas the FHA group recorded a substantially higher deviation of 21.2°. Similarly, the horizontal deviation, measured as the maximum distance from the desired position, was markedly lower for the DGEA group at 0.34 mm, compared to 0.88 mm in the FHA group. These findings suggest that the application of DNS enhances the benefits of ultra-conservative access cavities by minimizing the risk of iatrogenic damage to critical crown structures, while also reducing procedural risks, associated costs, and challenges in tissue removal and root canal examination.²⁷

Zubizarreta-Macho et al (2020) further investigated the precision of guided systems, comparing SGEA and DGEA with the free-hand approach. Their results revealed that DGEA provided superior accuracy, with mean deviations of 3.14 mm at the base and 2.48 mm at the tip, alongside an angulation error of 5.58°. In contrast, SGEA exhibited higher deviations, with 7.44 mm at the base, 7.13 mm at the tip, and an angulation error of 10.04°. The FHA method displayed the highest angulation error at 14.95°, along with deviations of 4.03 mm at the base and 2.43 mm at the tip. The study concluded that DGEA offered the most precise endodontic access cavities among the three methods, as demonstrated by lower deviation angles and reduced horizontal deviation at both the coronal entry point and apical endpoint.⁶²

Together, these findings highlight the advantages of guided endodontic techniques, particularly dynamic systems, in achieving more accurate and predictable outcomes compared to free-hand methods. The use of dynamic navigation not only enhances precision but also contributes to better preservation of dental structures and improved clinical efficiency.

Jain et al (2020) explored the use of a technologically advanced system incorporating optical guidance, computer assistance, and 3D navigation. Their system demonstrated efficient performance, achieving a mean horizontal deviation of 0.9 mm and a 3D divergence of 1.3 mm, with an average angular variation of 1.7°.²⁶ This technology proved effective for accessing difficult, calcified canals. Similarly, Dianat et al (2020) focused on comparing the DNS and FHA approaches. The DNS method exhibited superior efficiency, identifying root canals in 96.6% of cases compared to 83.3% for the FHA group.²⁹ Additionally, the DNS approach minimized tooth structure loss and reduced procedure time, emphasizing the significance of endodontist-led access cavity preparation. Kostunov et al³¹ (2020) evaluated guided versus conventional endodontics. While conventional methods located 100% of root canals, guided techniques achieved a 93.3% success rate. However, guided endodontics preserved more tooth structure, with incisors losing only 10.3 ± 1.1 mm³ of material. Despite these benefits, the guided approach involved higher radiation exposure, increased perforation risk, and greater costs, alongside challenges in removing dead tissue and inspecting canals. Similarly, Su et al (2021) examined the precision of guided access cavities. Their study revealed that 23 out of 117 cavities were initially inaccessible, though all were eventually accessed following canal negotiation. The study reported minimal deviations, with average linear deviations of 0.13 ± 0.21 mm at the coronal position and 0.46 ± 0.4 mm at the apical position, along with an angular deviation of 2.8 ± 2.6°. Notably, anterior teeth and premolars displayed better coronal precision than molars. The use of 3D-printed guides ensured precise access cavity preparation.¹

All four studies highlight advancements in guided endodontics and related technologies, emphasizing improved accuracy and preservation of tooth structure. Jain et al (2020) and Su et al (2021) both underscore the precision of new systems, though Su's study notes some initial accessibility challenges. Dianat et al (2020) and Kostunov et al (2020) provide valuable insights into the efficiency of different approaches, with Dianat emphasizing clinical effectiveness and Kostunov discussing trade-offs such as cost and radiation exposure. Together, these studies underline the evolving landscape of endodontic technologies, balancing precision with clinical practicality.^{1,26,31,58}

While guided endodontics offers precision, tissue conservation, and improved canal detection, it presents several challenges. Restricted mouth openings, especially in posterior teeth, can limit the use of templates, as noted by Gambarini et al (2020). The inflexible nature of templates also restricts the clinician's ability to modify the access axis during treatment. Additionally, template planning and manufacturing are time-consuming and labor-intensive processes.²⁷

Another limitation GE stated Hildebrand et al (2023) reported that guided methods required more radiographs than conventional techniques, increasing radiation exposure. The need for CBCT imaging, though essential for detecting complex root morphologies and pathologies, introduces higher radiation doses compared to conventional radiography.³³ Vasudevan et al (2023) also highlighted that static guided access (SGEA) achieved 100% canal success but was challenging to apply in patients with limited mouth opening, affecting posterior regions.³⁴

Another issue lies in operator training. El Hakim et al (2023) noted that experienced operators performed better in freehand techniques, though non-restrictive guides reduced the dependency on experience. Moreover, the cost and availability of CBCT equipment and rapid prototyping technology pose barriers to widespread adoption. Despite these limitations, dynamic navigation offers flexibility to overcome some template constraints, though clinical studies are needed to validate these systems further. Guided endodontics is a promising technique, but it requires further refinement in areas such as operator training, template design, accessibility in posterior regions, and the balance between radiographic requirements and patient safety.³⁵

Recent studies highlight the potential of guided endodontics to enhance access cavity preparation, minimize tooth substance removal, and improve treatment accuracy, regardless of the operator's experience. Future research should prioritize the refinement of nonrestrictive guide designs to overcome limitations found in static templates, such as restricted lateral movements during drilling and challenges when accessing posterior teeth.^{33,35} Additionally, assessing the real-time applicability of dynamic navigation systems in clinical environments is crucial, particularly for complex cases involving calcified or narrow-root canals.^{32,63} Another important focus is the advancement of affordable and accessible 3D printing technologies, which could make guided endodontics more practical for everyday dental procedures.²⁶ Furthermore, long-term clinical studies are necessary to confirm the effectiveness of guided approaches, particularly in maintaining the structural resilience of treated teeth and minimizing procedural errors over time.^{25,62}

The development of guided endodontics offers exciting potential, but there are still areas that require further exploration. One key aspect is the application of dynamic navigation systems in clinical practice to validate their reliability and reduce variability caused by different operator skill levels, especially when working on calcified or posterior canals.³⁴ Additionally, further improvements in minimally invasive access designs and their influence on the structural integrity and fracture resistance of treated teeth should be explored through longitudinal studies.

While integrating dynamic and static navigation systems has enhanced precision and reduced material loss, several challenges persist. Research is needed to assess the impact of DGEA on preserving tooth integrity, particularly in cases with complex anatomy or calcified canals.^{29,36} It is also essential to streamline guided systems by reducing the time and costs associated with intraoral scanning and guide production.^{27,29} Additionally, understanding how operator experience influences outcomes will aid in the development of standardized training programs, ensuring consistency across both static and dynamic navigation methods.^{27,36} Comparative clinical trials are needed to evaluate the clinical benefits of ultraconservative access cavities and their impact on long-term tooth durability, balancing the advantages of minimal invasiveness with effective cleaning.¹¹ Finally, the integration of DNS with technologies such as augmented reality or artificial intelligence could further enhance decision-making and precision during endodontic procedures.²⁹ In conclusion, guided access cavity preparation endodontic treatment using advanced technologies has shown great potential in improving the accuracy and predictability of endodontic therapy. Research shows that guided access cavity preparation endodontic treatment can improve dentin preservation and endodontic therapy accuracy. It is useful for root canal anomalies and difficult teeth, reducing unnecessary tooth removal and preventing complications. However, it is crucial for clinicians to consider its limitations and clinical applications before incorporating it.

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Disclosure

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