CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

Static endodontic guides in root canal treatment: Accuracy and conservation of the tooth

Agathe PLOUE

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

—

Gandra, maio de 2023

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

Agathe PLOUE

Dissertação conducente ao **Grau de Mestre** em **Medicina Dentária**
(Ciclo Integrado)

Static endodontic guides in root canal treatment: Accuracy and conservation of the tooth

Trabalho realizado sob a Orientação do Prof. Dr. Pedro Bernardino

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

DECLARAÇÃO DE INTEGRIDADE

Eu, acima identificado, declaro ter atuado com absoluta integridade na elaboração deste trabalho, confirmo que em todo o trabalho conducente à sua elaboração não recorri a qualquer forma de falsificação de resultados ou à prática de plágio (ato pelo qual um indivíduo, mesmo por omissão, assume a autoria do trabalho intelectual pertencente a outrem, na sua totalidade ou em partes dele). Mais declaro que todas as frases que retirei de trabalhos anteriores pertencentes a outros autores foram referenciadas ou redigidas com novas palavras, tendo neste caso colocado a citação da fonte bibliográfica.

ACKOWLEDGEMENTS:

First of all, I would like to thank Professor Pedro Bernardino for accompanying me throughout the year, both in the clinical courses and in my dissertation. Obrigada pela sua paciência e disponibilidade.

I would like to thank my parents for never having doubted me, for having always supported me in my schooling and in my choices. It is thanks to you that I am here today.

Thank you to my brother and my sisters; Juliette, Victor and Jeanne. I am very lucky to have you in my life. I love you all.

Thank you to my grandmother, for her kindness and generosity.

Thank you to Malek for the 5 wonderful years we have lived together, for always being there for me. Without you, these years would not have been the same.

Thank you to Sara, the best roommate, for all the memories and the beautiful years spent together.

Thanks to Zaineb and Yossi for their unwavering friendship since the beginning, thanks to you I have lived unforgettable moments here.

Thanks to Carla, Charla, Laulau, Jade, Clem, Noan and all the others for having marked these beautiful student years.

Thank you to my friends from France; Malice, Clémence, Anais, Ines, Nathan, Maria for this friendship which lasts in time.

RESUMO:

Introdução: A criação da cavidade de acesso é o primeiro e mais crucial passo no tratamento endodôntico. Embora possa ser frustrante e difícil, especialmente no tratamento de canais ou dentes calcificados com morfologias particulares. A endodontia guiada surgiu como uma alternativa viável para alcançar maior precisão e precisão nos procedimentos endodônticos.

Objectivo: Comparar as cavidades de acesso feitas com a técnica convencional ou feitas com uma guia endodôntica estática e avaliar a precisão e a conservação da estrutura dentária.

Métodos: Foi realizada uma pesquisa electrónica baseada em palavras-chave na base de dados PubMed. Os artigos publicados nos últimos 10 anos em língua inglesa e com texto integral disponível foram os critérios de inclusão utilizados.

Resultados : Dos 14 artigos seleccionados, 7 estudos discutem a precisão das guias endodônticas e a localização dos canais, 5 estudos compararam a preservação da estrutura dentária entre uma cavidade de acesso convencional e guiado e 2 artigos comparam a eficácia e abordam a resistência à fractura entre as técnicas convencionais e guiadas.

Conclusão: O resultado deste estudo indica que a endodontia guiada é um método seguro, simples e eficiente que mostra uma exactidão aceitável. Permitem a preservação de estruturas dentárias que são superiores às técnicas convencionais. Podem ser utilizados em tratamentos endodônticos mais complicados, tais como canais radiculares calcificados. No entanto, este método tem certas limitações e desvantagens.

Palavras-chave: Acesso endodôntico, tratamentos endodônticos, limitações, TCFC, acesso endodôntico guiado

ABSTRACT:

Introduction: Creating the access cavity is the first and most crucial step in endodontic treatment. While it can be frustrating and difficult, especially when treating calcified canals or teeth with particular morphologies. Guided endodontics has emerged as a viable alternative for achieving greater accuracy and precision in endodontic procedures.

Objective: Compare access cavities made with the conventional technique or made with a static endodontic guide and evaluate the accuracy and the conservation of tooth structure.

Methods: An electronic keyword-based search was performed on the PubMed database. Articles published in the last 10 years in English language and with full-text available were the inclusion criteria used.

Results: Of the 14 articles selected, 7 studies discuss the accuracy of endodontic guides and location of canals, 5 studies compared tooth structure preservation between a conventional and guided access cavity and 2 papers compare the efficacy and address the resistance to fracture between the conventional and guided techniques.

Conclusion: The result of this study indicates that guided endodontics is a secure, simple and efficient method that show an acceptable accuracy. They allow for the preservation of dental structures that are superior to conventional techniques. They can be used in more complicated endodontic treatments such as calcified root canals. However, this method has certain limitations and disadvantages.

Keywords: Endodontic access, endodontic treatments, limitations, CBCT, guided endodontic access

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

TABLE OF CONTENTS

INDEX OF FIGURES AND GRAPHS

INDEX TABLES

Abbreviatures:

ACP - Access Cavity Preparation

AOG-3DP - Access Opening Guide

CBCT - Cone Beam Computed Tomography

CEA - Conventional Endodontic Access

CEC - Contracted Endodontic Cavity

CT - Conventional Technique

DN - Dynamic Navigation

GE - Guided Endodontics

GEA - Guided Endodontic Access

GEC - Guided Endodontic Cavity

GT - Guide Technique

PCO - Pulp Canal Obliteration

RCT - Root Canal Treatment

SEG - Static Endodontic Guide

SN - Static Navigation

TEC - Traditional Endodontic Cavity

1. INTRODUCTION

The demand for root canal treatment (RCT) is increasing among elderly patients. (1) Root canal treatment (RCT) involves the clinician finding all the canals, shaping and cleaning them thoroughly, and filling them properly. Each step is crucial for the success of the treatment and the longevity of the tooth.(2)

The conventional design of the endodontic cavity has undergone minimal changes over several decades. Its purpose is to remove the roof of the pulp chamber entirely, so that the root canals can be detected and accessed through straight pathways, which improves the effectiveness of the instruments used. (3,4) Creating the access cavity is the first and most crucial step in endodontic treatment. While it can be frustrating and difficult, getting the design and preparation right is essential to ensure the best possible treatment outcome and avoid complications that could cause harm or failure of the procedure. (5)

Inaccurate location of the root canals can pose challenges during treatment and lead to various complications. These complications may include creating an access cavity that is too large, misalignment of the cavity that can lead to root perforation, and breakage of instruments used during canal preparation.(6,7) Moreover, failure to locate all root canals can lead to the accumulation of harmful microorganisms that contribute to the development of persistent apical periodontitis, ultimately leading to poor treatment outcomes. (5) In addition, one of the major difficulties faced by dental practitioners is to create an endodontic access that enables access to the root canals without causing unnecessary damage to the dental structures. Indeed, the extent of tooth structure that remains after the treatment is an important consideration that affects the tooth's stability and durability.(8)

There are situations where achieving proper traditional endodontic cavity (TEC) preparation is even more challenging, such as with teeth that have calcified pulp canals or anatomical irregularities.(9) Indeed, treating severely calcified canals through endodontic therapy is a daunting task, and it is correlated with a higher risk of technical malfunction and a decreased probability of success. (6,7). When failures result in perforations, 75% of them happen during the process of locating and navigating calcified canals. (7)

The emergence of modern radiographic technologies such as CBCT (Cone beam computed tomography) has brought about significant advancements in treatment planning and diagnosis, leading to the progression of the field of endodontics.(9) In recent times, a new approach to endodontic treatment called guided endodontics (GE) has been introduced by researchers. This technique involves the use of 3D-printed guides to prepare access cavities. The concept of GE is similar to guided implant surgery, which was previously reported. In GE, 3D information from intraoral scans and CBCT is used to create virtual access cavity plans and design a template through computer-aided design software. The template is then produced using 3D printing, and the cavity preparation is carried out with drills. The use of GE is an evolution in endodontics facilitated by the development of new radio diagnostic technologies such as CBCT. (10–12).

The use of GE has demonstrated its efficacy in cases where access to the root canal system is required in calcified teeth, cases involving dens evaginatus or dens invaginatus, and in cases of endodontic surgeries. (8,11). A minimal invasive access cavity that is virtually planned and guided could be beneficial in preserving tooth structure and preventing perforations. This approach may result in an improved long-term prognosis for teeth with calcified root canals. (1)

2. OBJECTIVES AND HYPOTHESIS

The primary objective was to compare access cavities made with the conventional technique (CT) or made with a static endodontic guide (SEG) in terms of accuracy and conservation of tooth structure.

The secondary objectives were to show the application, limits and disadvantages of the technique

The null hypothesis considers there is no difference between CT and SEG regarding the accuracy and conservation of tooth structure

3. MATERIAL AND METHOD

3.1 Protocol

This study was realized in accord with the directives PRISMA (Preferred Reporting Items for Systematic and Meta-Analyses).

3.2 Eligibility Criteria

This work was recommended according to Cochrane's recommendations responding to PICO (Population; Intervention; Comparison; Outcome).

Table 1: PICO

Population	Teeth that require root canal treatment
Intervention	Use of SEG
Comparison	With CT access cavity
Outcome	Analizing the accuracy of SEG and their ability to make conservative cavity.

The eligibility criteria were divided into two groups, the inclusion and exclusion criteria:

Table 2: Eligibility criteria

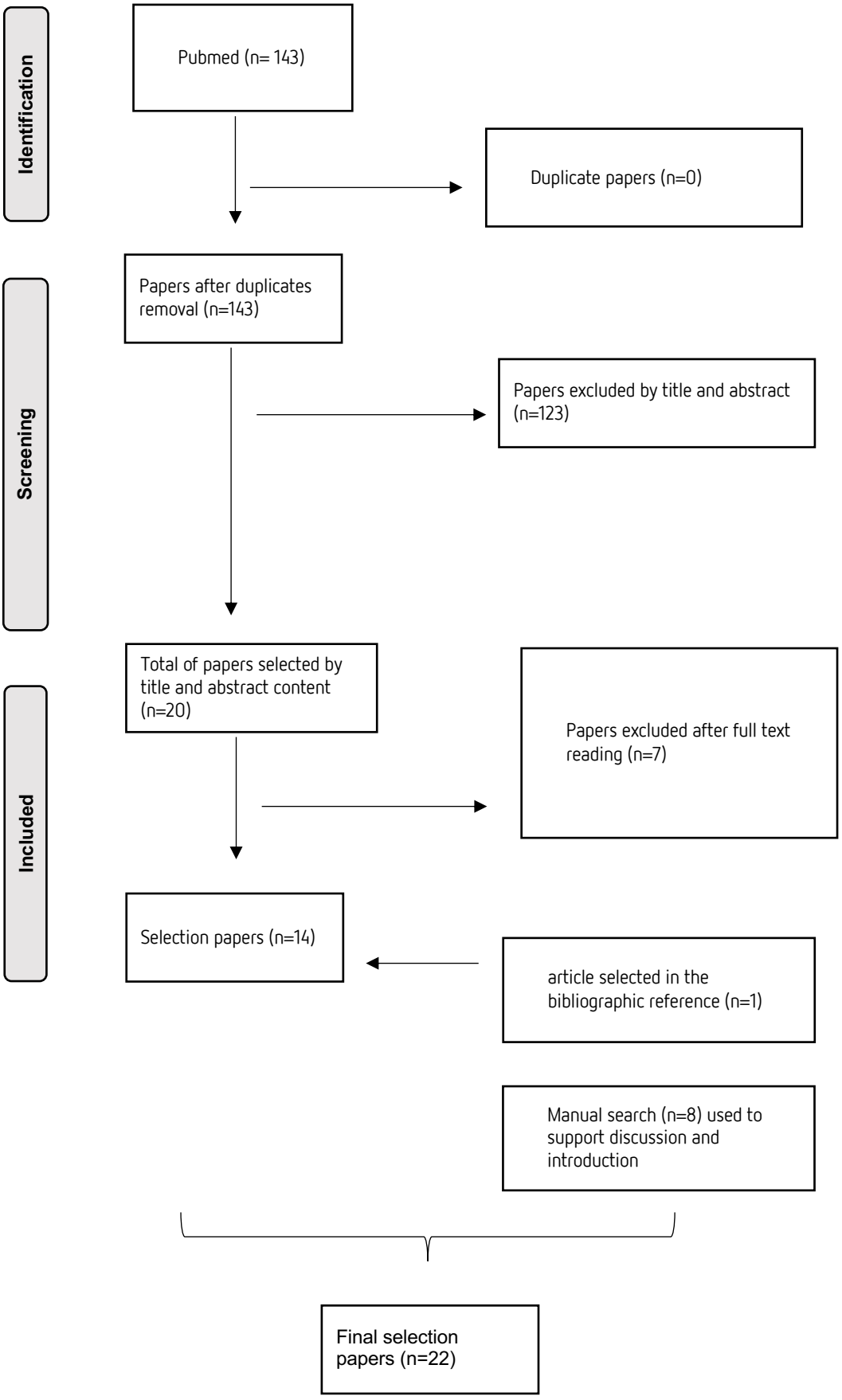
Inclusion criteria	Exclusion criteria
• Articles published in the last 10 years • Articles in English • Studies about endodontic static guides • Study including all types of teeth (incisive, canine, premolar, molar) • Ex vivo study, in vitro study, comparative study, observational study	• Articles without full text • Duplicates • Articles not related to endodontic static guides: articles related about endodontic dynamic guides and microsurgery guides • Systematic review and case report • Books and documents • Irrelevant articles

3.3 Searching for information

This literature search was conducted in the PubMed databases (via the National Library of Medicine) between March 2023 and March 2013 with the combination of the following scientific MeSH terms: "endodontic access" AND "endodontic treatments" AND "limitations" AND "CBCT" OR "guided endodontic access"

Other supporting articles for the introduction and discussion were obtained with a free manual search.

Figure 1- PRISMA fluxogram – the research strategy used in this study



4. RESULTS

4.1 Selection of articles

In the search for studies, PubMed was the only search engine used. A total of 143 articles were found. After applying the exclusion criteria, reading the titles and contexts, 20 articles were selected. Then after reading these 20 articles, 7 were excluded and one is included thanks to the bibliographic reference. Of these 7 articles, 2 were about dynamic endodontic guides, 1 was about microsurgery endodontic guide, 4 were case report.

Finally, 14 articles were included in this integrative systematic review.

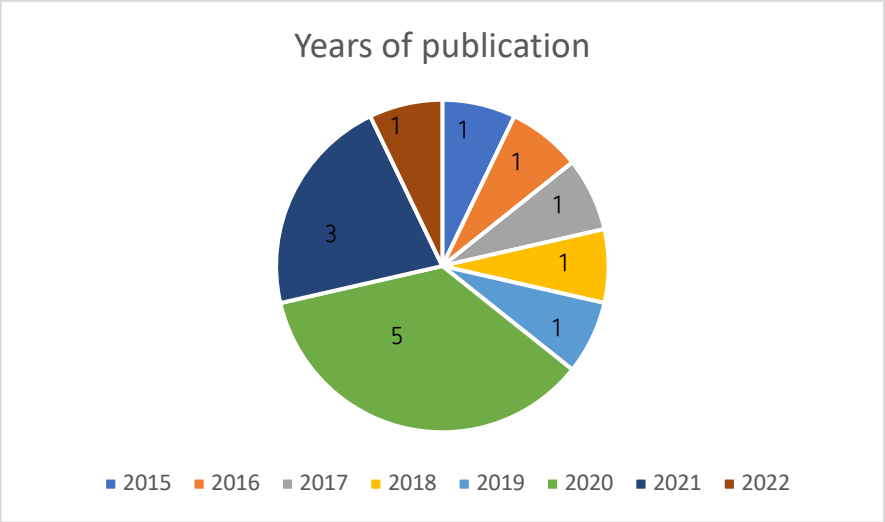
With the free manual search, 8 articles were found to support the introduction and discussion.

4.2 Characteristics of the studies included

4.2.1 Year of publication

Regarding the publication period, the year 2020 recorded the highest number of articles on the topic in question, presenting 5 articles (36%), the year 2021 with 3 articles (22%) and finally the year 2015, 2016, 2017, 2018, 2019, 2022 with one article each (7%). No articles were selected from the years 2013, 2014 and 2023.... Figure 2 shows the distribution regarding the years of publication.

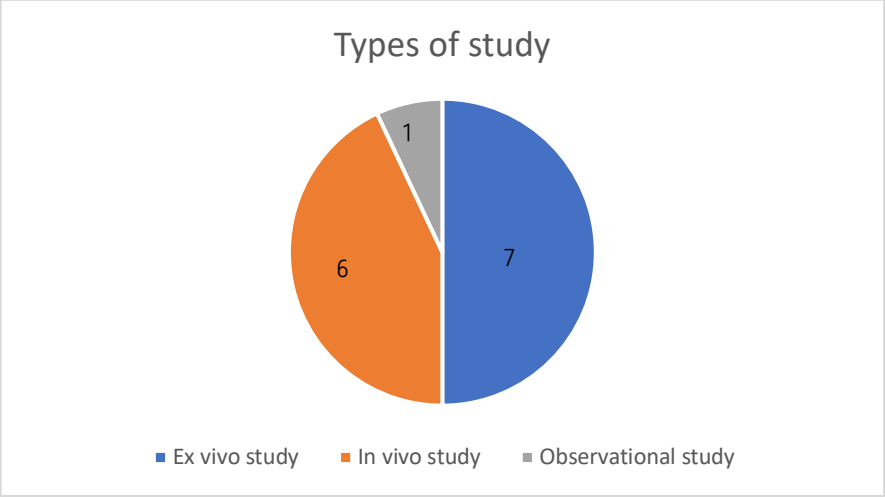
Figure 2-Distribution by year of publication of the articles included



4.2.2 Types of studies

Regarding the type of studies of the articles evaluated, 1 is observational (7%), 6 are in vitro studies (43%) and 7 are ex vivo studies (50%).

Figure 3- Distribution according to the type of study



4.2.3 Main objective of studies

Of the 14 articles selected, 7 studies discuss the accuracy of endodontic guides and location of canals (50%), 5 studies compared tooth structure preservation between a conventional and guided access cavity (36%) and 2 papers compare the efficacy and address the resistance to fracture between the conventional and guided techniques (14%).

Figure 4- *Distribution according to the main objective of studies*

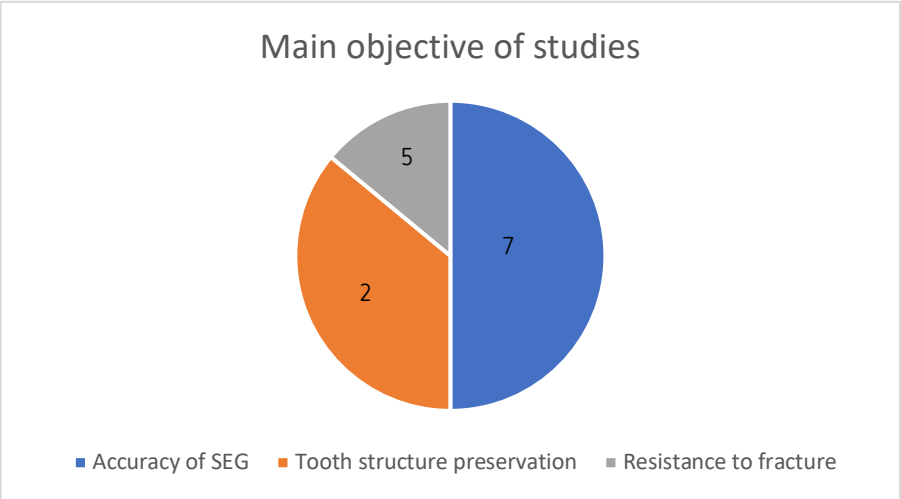


Table 3: Relevant data gathered from the selected studies

Title/Authors/year	Purpose	Materials and Methods	Preparation of guides and specifications	Results	Conclusion
Guided access cavity preparation using cone-beam computed tomography and optical surface scans – an ex vivo study **J. Buchgreitz et al. (2015)** Ex vivo study	Evaluate ex vivo, the accuracy of a preparation procedure planned for teeth with pulp canal obliteration (PCO) using a guide rail concept based on CBCT scan merged with an optical surface scan.	**48 teeth** mounted in 12 acrylic blocks (4/5 teeth per blocks) An apical canal preparation was created to simulate remnants of an apical root canal The distance was measured between the centers of the performed drill path and the apical target by two examiners. A maximum distance of 0.7 mm was defined based on the radius of the bur (0.6 mm) and the radius of a root canal just visible on a radiograph (0.1 mm).	Virtual design drill path: **A CBCT scan** (Orthophos XG 3D unit, Sirona Dental Systems, Bensheim, Germany) **Drill path:** diameter of 1.2 mm **Sleeve:** inner diameter 1,2mm, length 4mm Guide rail construction: **Surface scanned** (CEREC, Sirona Den- tal Systems) **CBCT image** (Galaxis/Galileos Implant, Sir- ona Dental Systems **3D printer:** CNC technology as a SICAT optiguide (SICAT, Bonn, Germany) **Bur:** diameter 1,2 mm, working length 22mm	Null hypothesis H_0: I = 0.7: rejected (CI 95%: 0.31;0.49, P < 0.001) The mean distance between the drill path and the target was significantly lower Intra and interexaminer agreements reached excellent levels.	The combined use of CBCT and optical scans for the precise construction of a guide rail led to a drill path with a precision below a risk threshold. The present technique may be a valuable tool for the negotiation of partial or complete PCO.
Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location	Present a novel method utilizing 3D printed templates to gain guided access to root canals and to evaluate its accuracy in vitro.	**60 extracted teeth (incisors, laterals, canines and premolars)**: 6 maxillary jaw models 2 operators are doing cavities using SGE	**CBCT images** (Morita Accuitomo 80, J.MORITA Mfg. Corp, Kyoto, Japan) : voxel size : 0.125 mm	All root canals were accessible after access cavity preparation (ACP) with SGE **Deviations at the base of the bur:** 0.16 to 0.21 mm	SGE allowed an accurate ACP up to the apical third of the root utilizing printed templates for guidance.

M. S. Zehnder et al (2016) In vitro study			**3D-intra-oral surface scanner** (iTero, Align Technology Inc., San Jose, CA, USA) **Planning software** (coDiagnostiX™ version 9.2, Dental Wings Inc., Montreal, Canada) **Bur:** total length of 37 mm / working length of 18.5 mm / diameter of 1.5 mm / speed at 10 000/min **Sleeve:** inner diameter of 1.5 mm / external diameter of 2.8 mm / length of 6 mm **3D printer** (Objet Eden 260 V, Material: MED610, Stratasys Ltd., Minneapolis, MN, USA)	**Deviations at the tip of the bur:** 0.17–0.47 mm **Mean of angle deviation:** 1.81° Overlapping 95% confidence intervals revealed no significant difference between operators.	All root canals were accessible after preparation.
Microguided Endodontics: Accuracy of a Miniaturized Technique for Apically Extended Access Cavity Preparation in Anterior Teeth **Thomas Connert et al. (2017)** In vitro study	Assess the accuracy of SGE in mandibular anterior teeth by using miniaturized instruments	60 mandibular anterior teeth in 10 mandibular models 2 operators with **5 models (n=30) teeth per operators**	**CBCT scan** with a voxel size of 80 mm **Three-dimensional (3D) intraoral scanner** (iTero; Align Technology Inc, San Jose, CA) **Software:** (coDiagnostiX Version 9.2; Dental Wings Inc, Montreal, Canada) **Bur:** working length of 20 mm, 0.85 mm diameter **Sleeve:** inner diameter of 0.88 mm, outer diameter of 4 mm, and a length of 6 mm	**Deviations between the planned and prepared access (base of the bur):** 0.12 to 0.13 mm **Deviations between the planned and prepared access (tip of the bur):** 0.12 to 0.34 **Angle deviation:** 1.59. No significant difference between the operators. **Treatment time (planning and preparation):** 10min/ tooth	Microguided endodontics provides an accurate, fast, and operator-independent technique for the preparation of apically extended access cavities in teeth with narrow roots such as mandibular incisors

Guided Endodontics versus Conventional Access Cavity Preparation: A Comparative Study on Substance Loss Using 3-dimensional–printed Teeth **Thomas Connert et al. (2018)** In vitro study Comparative study	Compare endodontic access cavities in teeth with calcified root canals prepared with the conventional technique (CT) and a guided endodontics (GT)	6 identical sets of upper and lower jaw models were produced with 3-dimensional–printed incisors that had simulated calcified root canals **Group 1 (GT):** 6 sets (3upper and 3lower) **Group 2 (CT):** other 6 sets **8 teeth per technique and operator** 3 operators (different levels of experience)	**Preoperative CBCT** scan with a voxel size of 125 mm STL files through a **3D intraoral scanner** and DICOM data uploaded to **coDiagnostiX software (Version 9.2, Dental Wings Inc)** Both scans were matched by aligning the contours of the teeth **Bur =** diameter 0.85 mm Sleeve = inner diameter 0,88mm **3D printed** (Objet Eden260 V, material: MED610; Stratasys Ltd).	**Canal location:** CT: 10 of 24 cases (41.7%) GT: 22 of 24 cases (91.7%) **Substance loss:** CT : 49.9 mm^3 (95% CI, 42.2–57.6 mm^3) GT : 9.8 mm^3 (95% CI, 6.8– 12.9 mm^3) **The treatment lasted:** CT: 21.8 minutes (95% CI, 15.9–27.7 minutes GT: 11.3 minutes (95% CI, 6.7–15.9 minutes) for GT. The success of the guided approach was not influenced by the experience of the operator.	SGE allows a more predictable and expeditious location and negotiation of calcified root canals with significantly less substance loss.
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 **J. Buchgreitz et al. (2019)** Observational study	To report the precision of guided access cavity preparations in relation to demographic and dental variables in fifty patients.	Period 2014-2017 **50 patients (30 F / 19H)** **Inclusion criteria:** - PCO associated with signs of apical periodontitis (88%) - Teeth with PCO in need of a post (12%) - A surgical intervention was not justified	**CBCT scan** (Orthophos XG 3D unit, Sirona Dental Systems, Bensheim, Germany) **Software** (Galaxis/Galileos Implant, Sirona Dental Systems) **Surface scanned** (CEREC, Sirona Dental Systems) **SICAT optiguide** (SICAT, Bonn, Germany) **Drill path:** diameter of 1,2mm **Final preparation of the canal:** reciprocating file sizes 25-50 / endodontic handpiece	**PCO:** longer in maxillary compared with mandibular teeth **The performance of the drill path:** precision in mandibular teeth > maxillary teeth (P = 0.033) Even in cases with the worst outcome the technique was still successful clinically.	The clinical implementation of guided root canal treatment in fifty serial cases of single-rooted teeth with PCO was associated with a precision that in all cases led to the location and negotiation of the root canal and completion of the treatment.

Impacts of contracted endodontic cavities compared to traditional endodontic cavities in premolars **Juan Xia et al. (2020)** Ex vivo study Comparative Study	Compare the percentage of dentin removed, instrumentation efficacy, root canal filling and load at fracture between contracted endodontic cavities, and traditional endodontic cavities on root canal therapy in premolars.	**40 extracted intact human first premolars** **Group 1:** Contracted endodontic cavity (CEC) groups (with guide) ***Group 1a:*** single-rooted mandibular first premolars with one root canal ***Groupe 1b:*** two-rooted maxillary first premolars with double root canals **Group 2:** traditional endodontic cavity (TEC) groups. **Group 2a:** single-rooted mandibular first premolars with one root canal ***Group 2b:*** two-rooted maxillary first premolars with double root canals	**CEC group:** **High- resolution** CBCT scan **Simplant** (SIMPLANT, Materialise Dental, Leu- ven, Belgium) **Freeform** (Geomagic Freeform, 3D Systems, Morrisville, North Carolina, USA) **3D printer** (3D System 3510HB, 3D Systems, Morrisville, North Carolina, USA) **Bur:** high speed **TEC group:** 0.04 taper M-Two rotary instruments (35#) **TEC and CEC group:** Obturated with **gutta-percha** cones **and 2 mm composite resin** restorative material on the canal opening	**Percentage of dentin (premolars with two roots):** TEC groups: (4.94% ± 0.5%) CEC groups: (3.85% ± 0.42%) **The untouched canal wall (UCW) after instrumentation (premolars with single root):** TEC groups: 6.43% ± 6.56% CEC groups: 24.42% ± 9.19% **Increased canal volume and surface areas between the TEC and CEC groups (P > 0.05):** No significant differences CECs conserved coronal dentin in premolars with two dental roots but no impact on the instrument efficacy. **Percentage of filling material and voids (P > 0.05):** No differences between the 2 groups **Mean load at failure:** No significant difference in the type of fracture (P > 0.05)	The results of this study suggest that CEC could not improve the fracture resistance of the endodontically treated premolars. The instrumentation efficacy and the percentage of filling material did not significantly differ between CECs and TECs in premolars.
Accuracy of Computer-Aided Dynamic Navigation Compared to Computer-Aided Static Procedure for Endodontic Access Cavities: An in Vitro Study	Analyze the accuracy of two computer-aided navigation techniques to guide the performance of endodontic access cavities compared with the conventional access procedure.	**30 lower central incisors:** 3 models of epoxy resin **Group 1:** guided performance of endodontic access cavities through computer-aided static navigation system (n = 10) (SN);	**Group 1:** **CBCT scan,** exposure parameters: 105.0 kilovolt peak, 8.0 milliamperes, 7.20 s, and a field of view of 15 × 13 mm	No statistically significant differences between SN and DN at the **coronal** (p = 0.6542), **apical** (p = 0.9144), or **angular** (p = 0.0724) level Statistically significant differences were observed between the SN, DN	Both SN and DN procedures allowed accurate performance of endodontic access cavities.

Álvaro Zubizarreta-Macho et al. (2020) Ex vivo study Comparative Study		**Group 2:** guided performance of endodontic access cavities through computer-aided dynamic navigation system (n = 10) (DN) **Group 3:** manual (freehand) performance of endodontic access cavities (n = 10) (MN).	**3D-extraoral scanner** (EVO, Ceratomic, Protechno, Girona, Spain) **3D implant planning software** (NemoScan®, Nemotec, Madrid, Spain) **Bur:** diameter of 1.2 mm, length of 14 mm, drilling depth of 11 mm **Group 2:** Monitored by the laptop computer **of the computer-aided dynamic navigation system (Navident, ClaroNav)** **Group 3:** CBCT scan and datasets were uploaded to 3D implant planning software but **no template**	techniques and the MN group at **the coronal** ($p < 0.0001$), **apical** ($p < 0.0001$), and **angular** ($p < 0.0001$) level.	
Minimization of Tooth-Substance Removal in Normally Calcified Teeth Using Guided Endodontics: An In-Vitro Pilot Study **Jana Kostunov et al. (2020)** In vitro study Comparative Study	Evaluate the success rate of, and tooth-substance removal required for, SGE preparation of access cavities	**30 acrylic typodont teeth with root canals** (10 each of tooth numbers 11, 14, and 17) **Control group (n=15):** CT **Study group (n=15):** SGE preparation of endodontic access cavities	**Study group:** **CBCT scan:** Field of view (sphere with a diameter of 15.4 cm, 12 bits; scan time: 14 sec, 357 images; voxel size: 0.25 × 0.25 × 0.25) **CoDiagnostix software** (Dental Wings; Montreal, Canada) **Bur:** diameter of 1,6mm	**Canals located successfully:** - CT group: 93.3% - SGE group: 100% **Mean tooth substance removal:** -CT group: 16.1 ± 3.7 mm3 for incisors, 44.2 ± 8.9 mm3 for premolars 99.3 ± 3.1 mm3, for molars - SGE group: 10.3 ± 1.1 mm3 for incisors, 29.3 ± 4.2 mm3 for premolars	Use of SGE in normally calcified teeth enables preservation of a significant amount of tooth substance.

			Control group: High speed Contra angle handpiece, cylindrical diamond bur with rounded edges	51.8 ± 5.3 mm3 for molars.	
Guided Endodontics: Volume of dental tissue removed by guided access cavity preparation – an ex vivo study **Marco Antônio Z Loureiro et al. (2020)** Ex vivo study Comparative Study	To compare the volume of dental tissue removed after guided endodontic access (GEA) and conventional endodontic access (CEA) to mandibular incisors and upper molars.	**20 extracted human mandibular incisors and upper molars** **Group 1:** mandibular incisors G1a (CEA) / G1b (GEA) **Group 2:** maxillary incisors G2a (CEA) / G2b (GEA)	**Tomograph:** PreXion 3D FOV: 56.00 mm x 56.00 mm, voxel 0.1 mm, voltage 90 kVp, current 4 mA, exposure time of 33.5 s **Virtual drawing:** *Blue Sky Plan*® software **3D printer** (Straumann® CARES® P30) **Guides:** minimum thickness of 3 mm of resinous material **Bur:** diamond tips n. 1011: 1.3 mm in diameter and 20 mm long **Sleeve:** 1.5-mm internal diameter	**Volume reduction:** G1a group: 31.667mm³ (10.62%) G1b group: 26.523mm³ (10.65%) - no significant difference: p = 0.960 G2a group: 62.526mm³ (5.86%) G2b group: 45.677mm³ (4.11%) - significant difference among p = 0.004	GEA preserved a greater volume of dental tissue in extracted upper human molars than CEA; however, there was no significant difference between CEA and GEA in the volume of dental tissue removed from mandibular incisors.
Effectiveness of the static-guided endodontic technique for accessing the root canal through MTA and its effect on fracture strength **Afzal Ali et al (2020)** Comparative Study Ex vivo study	Evaluate the effectiveness of the SEG technique for accessing the root canal through the mineral trioxide aggregate (MTA) Evaluate the effect of this technique on the fracture strength of teeth.	**30 mandibular premolars** **Control group (n=15):** Composite resin and MTA removed without any guide. **SEG-access group (n=15):** Composite resin and MTA removed with a guide.	**Control group:** **Dental loupe** (× 4.2 magnification, Amtec, India) **Diamond high-speed bur:** diameter of 1.6 mm on the active part **SEG access group:**	**Mean time:** SEG-access group < control group Mishaps did not occur in the SEG-access group The SEG-access group exhibited the significantly preserved fracture resistance of the teeth as compared with the control group (P < 0.05). Non-restorable failure occurred more frequently in the control group than in the SEG-access group.	Within the limitations of the present study, the SEG technique yielded favorable results with respect to time, mishaps, and fracture strength.

			CBCT (GE Healthcare, USA) scan: thickness of 0.65 mm per slice, and parameters of 84 kV, 6.0 Ma, and 12 s **Extraoral scanner** (D710 scanner, 3Shape) **Planning software** (SIMPLANT, Dentsply Implants) **3D printer** (ProJet 6000, 3D Systems) **Guides:** stereolithography resins **2 groups:** Obturation + Flowable and hybrid composite resins		
The effects of endodontic access cavity design on dentine removal and effectiveness of canal instrumentation in maxillary molars **Dan Wang et al (2021)** Comparative Study Ex vivo study	Evaluate the impact of three designs of endodontic access cavities on dentine removal and effectiveness of canal instrumentation in extracted maxillary first molars using micro computed tomography (micro- CT).	**30 extracted intact maxillary first molars** **Group 1:** The traditional endodontic cavity (TEC) group **Group 2:** The conservative endodontic cavity (CEC) group **Group 3:** The guided endodontic cavity (GEC) group. Operator: endodontic specialist with more than 10 years of experience	**TEC Group:** High-speed handpiece, spherical **diamond bur with a diameter of 1,2mm + endo Z** **CEC Group:** High-speed handpiece, spherical **diamond bur with a diameter of 1,2mm + endo Z** **GEG Group: CBCT** data and **3D optical scanning** data of teeth	**Volume of dentine removed:** ++ in the TEC group after root canal preparation ($p < .05$) No significant different between the CEC and GEC groups ($p > .05$) **Volume of dentine removed in the crown, peri cervical dentine and coronal third of the canal:** CEC and GEC groups < TEC group ($p < .05$), **Volume of dentine removed in the middle and apical third of the canal:** No difference between 3 groups ($p > .05$).	In extracted maxillary molars tested in a laboratory setting, CEC and GEC preserved more tooth tissue in the crown, peri cervical dentine and coronal third of the canal compared with TEC after root canal preparation. The design of the endodontic access cavity did not impact on the effectiveness of canal instrumentation in terms of non-instrumented canal area, canal transportation and centring ratio.

			Dental Navi software (Yaker) **Drill path:** diameter of 1,7mm **3D printer** (Form 2; Formlabs Inc.) **Spherical diamond bur:** (diameter, 1.2 mm; length, 25 mm)	**Non instrumented canal area, canal transportation and centring ratio:** No significant difference between 3 groups ($\rho > .05$)	
Guided endodontics: accuracy of access cavity preparation and discrimination of angular and linear deviation on canal accessing ability—an ex vivo study **Yinghui Su et al (2021)** Ex vivo study	Evaluate the accuracy of 3 dimensional (3D)-printed endodontic guides for access cavity preparation in different types of teeth Evaluate the predictive ability of angular and linear deviation on canal accessibility ex vivo.	**84 teeth** mounted into 6 jaw models **Group 1**: anterior teeth (AT) **Group 2:** premolar (P) **Group 3**: molar (M).	**CBCT** with a voxel size of 150 μm **Intraoral scanner** (3Shape TRIOS, 3Shape, Copenhagen, Denmark) **Superimposed in dental CAD software** (Implant Planning, Inteware, Chiayi, Taiwan) **Bur diameter:** 0,5mm Bur lenght: 16mm **Resin sleeves: 1**.09-mm inner diameter and a 3-mm sleeve height	23/117 record as canal inaccessibility, but all accessible after negotiation **The average linear deviation:** - 0.13 ± 0.21 mm at coronal position - 0.46 ± 0.4 mm at apical position - 2.8 ± 2.6° in angular deviation **Linear deviations at the coronal and apical position and angular deviation:** - AT and P groups < M group ($P < 0.05$) - No statistically significant difference between AT group and P group **Area under the ROC curve:** - 0.975 in angular deviation - 0.562 in linear deviation at the coronal position - 0.786 at the apical position Statistical significance was noted in linear deviation at the apical position and in angular deviation ($P < 0.001$).	This study demonstrated that the accuracy of access cavity preparation with 3D-printed endodontic guides was acceptable. The linear and angular deviations in the M group were significantly higher than those in the other groups, which might be caused by the interference of the opposite teeth. Angular deviation best discriminated the canal access ability of guided access cavity preparation.
Access opening guide produced using a 3D printer (AOG-3DP) as an effective tool in difficult cases for dental students	Determine the effectiveness of using an access opening guide in teaching ideal access opening shape and preventing excessive tooth	**90 teeth** that were mounted in a box using tray resin **Study group:** access opening guide (AOG-3DP)	**Mimics software** (Materialize, Leuven, Belgium) was used to convert the CBCT images into Stereo Lithography (STL) files of 3D reconstructions	**The mean times premolars/ molars:** Control group: 327.2s / 547,4s AOG 3DP group: 97.4s /104,5s	Using the AOG-3DP significantly reduced the access opening time for premolars and molars.

Yiseul Choi BSDH et al (2021) In vitro study Comparative study	loss, with a focus on predoctoral dental students.	**Control group:** without guide	**Exocad software design three-unit AOG-3DP** (Tough resin) **#330 bur, diamond bur, and Endo Z**	**The mean volumes premolars/ molars:** Control group: 38.1 and 72.2 mm^3 AOG-3DP group: 2.0 and 8.7 mm^3	
The accuracy of using guided endodontics in access cavity preparation and the temperature changes of root surface: an in vitro study **Cuifeng Zhang et al. (2022)** In vitro study	Evaluate the accuracy and degree of temperature transmitted to the root surface using the endodontic guide	**58 teeth** **Experience 1:** n=40 premolars (single-rooted) **Experience 2:** n=18 divided into 3 groups ***Control group:*** ET20 (n=6) and ProTaper F3 (n=6) ***Test group:*** guided endodontics (n=6)	**CBCT scanner** at 110kV, 3~9mA, a field of view of 8cm×12cm, a basic voxel size of 0.30mm **Intra oral scanner:** Trios intra-oral scanner (TRIOS 3, 3Shape, Denmark). **3D printer** (Projet 7000MP, 3D System Int, USA): epoxy resin **Bur** :0.8mm diameter and 18mm work length **Sleeve for guided diamond:** 1,4mm diameter -> remove enamel and dentine **Sleeve for custom guided bur: 0**,8 mm diameter –>apical third of the root	**Average deviation on the tip and the base of the bur:** - 0.30 mm and 0.28mm (mesial/distal) - 0.28 mm and 0.25 mm (buccal/lingual) **Average angle deviation:** 3.62° The mean root surface temperature rise of the guided endodontics group was the lowest (5.07 °C) ($P < 0.05$).	The access cavity preparation performed with guided endodontics has feasible accuracy and low- temperature rise on the root surfaces. Due to the limitations of the study, whether it has high reliability and safety in clinical applications needs to be further studied in vivo.

5. DISCUSSION

5.1 Indication and application of guided endodontics

5.1.1 Purpose

The creation of endodontic access cavities is considered a key element of successful endodontic treatment, but it is also one of the most difficult and frustrating parts. Thus, proper design and careful preparation of the access cavity are crucial to ensure quality treatment, avoid iatrogenic problems and prevent failure. In addition, inaccuracies can make root canal identification more difficult and lead to unforeseen difficulties. (5) Indeed, it is common to encounter various problems during the access opening phase, including excessive tooth loss, furcation perforation and inappropriate access geometry. (12) For these reasons, in some cases, freehand preparation of the access cavity may be difficult. (9) To combat these problems, a new approach called "Guided Endodontics" has been introduced, which provides a guided method for creating extensive apical access cavities.(13) Indeed, the integration of technology, such as virtual planning software and 3D printers, has revolutionized the field of dentistry, particularly in implantology and endodontics. The use of this system can avoid over-preparation and facilitate the process of locating orifices (2). It can produce accurate design and positioning, as well as effective pre-procedural communication. (4) This will allow to create a minimally invasive cavity, virtually planned and to preserve tooth structure and avoid perforations, thus improving long-term prospects.(1) This device has the potential to improve not only the skill and reliability of individual clinicians, but also patient satisfaction.(2)

5.1.2 Indications

Recently, guided endodontics has gained popularity in the management of calcifications, anomalous teeth, fiber post removal, dens evaginatus, access cavity preparations in the normal tooth, and micro-endodontic surgical procedures. (11)

First of all, this technique is frequently used in cases of root canal calcification.

Pulp canal obliteration (PCO) or calcific metamorphosis is a process associated with injury to the pulp and it is characterized by the deposition of hard tissue within the root canal space. This process can present as a result of tooth trauma, caries, tooth surface loss or operative procedures such as pulp capping, pulpotomy and rarely orthodontic treatment. During root canal treatment, localizing the root canal can be a difficult and time-consuming task. For that, the Guided Endodontics technique may be a valuable tool for the negotiation of pulp canal obliteration, reducing chair time and risk of iatrogenic damage to the root. (14)

In addition, the use of guides can also be useful for the treatment of invaginatus teeth. An enamel-lined developmental malformation called dens invaginatus occurs as an invagination in the surface of the crown during tooth development. The exact etiology is still unclear. But it is believed that genetic factors, trauma, infection, focal growth retardation/ acceleration on the tooth bud, and restriction of the dental arch on the enamel organ are the causal elements. For this reasons, navigation of the main root canal and dealing with a dens invaginatus is a challenging task in clinical practice. To answer this, the guided endodontic technique has created a conservative access to invaginatus teeth and their canals. This technique minimizes the risk of iatrogenic damage, work time, and provides precise access to canals.(15)

Moreover, the use of guide is also important when the teeth have complex morphologies. Although the general root canal anatomy of a normal tooth and other anatomic variations have been identified in many morphologic studies, clinicians may still encounter a root canal system with an aberrant morphology, resulting in great difficulties even in accessing root canals. In this difficult case, the use of a transparent guiding model including the pulp chamber and root canals can lead to safer and more accurate endodontic treatment by understanding the complex morphologies of abnormal teeth. (16)

Finally, this tool can also assist in surgical endodontic treatments. Endodontic microsurgery is, in its broadest sense, defined as the treatment performed on the root apices of an infected tooth, which was unresolved with conventional root canal therapy. Generally, procedure for endodontic microsurgery encompasses the removal of the buccal bone in order to accurately locate the root apices of an infected tooth, which may include the

removal of intact bone. Nevertheless, direct intra-oral localization of root apex based on the 3D information is extremely difficult and significant amount of bone removal is inevitable when freehand surgical procedure was employed. Endodontic microsurgery using the guide template could be useful method in calcified canal which was untreatable with conventional root canal therapy and unable to track the position of the apex due to the absence of fistula. (17)

5.1.3 Application protocol

These methods require preoperative CBCT and 3D surface scans to plan the treatment. This digital process provides a comprehensive understanding of the patient's anatomy and allows for improved treatment planning.

First, a CBCT Preoperative is performed, and data are saved in Digital Imaging and Communication in Medicine (DICOM) format.

After this, the models are scanned with an intraoral scanner, and surface data is saved in the stereolithography (STL) file format.

Then, both types of data are superimposed in dental CAD for virtual access cavity planning. Virtual templates are designed by matching the 3D surface scan and CBCT data to key points of the teeth's crown. The positions and axes for access cavity preparations are planned virtually.

Finally, a template is 3D-printed, and sleeves for guided endodontics are incorporated. (1–22)

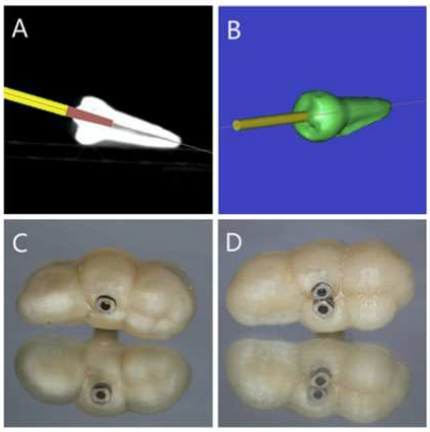


Figure 5- A. The drill virtually superimposed on the tooth to create straight-line access to the apical third of the root canal. B. A schematic of a drill in the tooth model. C. A 3D-printed template positioned on the single-rooted premolar model. D. Template positioned on the premolar with two dental roots (4)

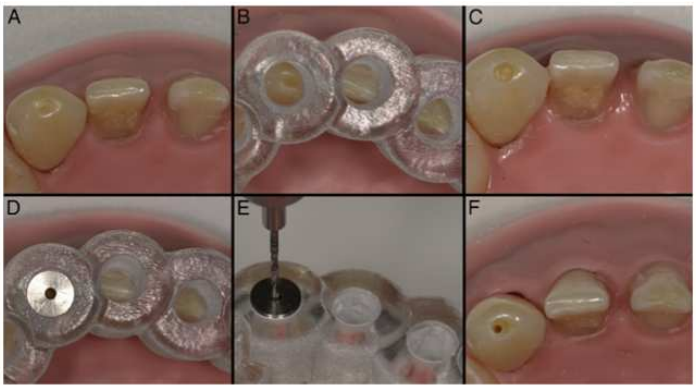


Figure 6- Clinical procedure for microguided endodontics : (A) preoperative situation, (B) adaption of the template, (C) removal of the enamel until the dentin is exposed, (D) template with incorporated sleeve, (E) guided preparation through the sleeve, and (F) access cavity according to planning.(18)

5.2 Advantages of the technique

5.2.1 Accuracy

Recently, pre-clinical studies have been conducted to assess the reliability of guided endodontics and have shown that it has a high level of accuracy. These studies show that guided endodontics is very accurate, with little impact from the operator or the software used for design and measurement. (1,6,9,10,12,18)

First, endodontic guides have higher accuracy than implant guides. It could be attributed to the use of a single burr, as opposed to the multiple burrs of different diameters required for implant cavity preparation, which could potentially increase the margin of error. (1,18)

Indeed, the accuracy of the guided endodontic technique has been found to be reliable in several studies:

Buchgreitz et al. evaluated the accuracy of guide endodontic access for pulp canal obliteration and determined that the combined use of the technique results in a drill path with accuracy below a risk threshold. A limit was established (I = 0.7 mm) for the maximum acceptable distance between a clearly defined apical target point and the center of the drill path in dentin. The present measurements showed a significantly smaller mean distance of 0.46 mm ($P < 0.001$ (95% CI; 0.31-0.49)). (12)

Similarly, *Zehnder et al.* evaluated the accuracy of the guided endodontic technique in preparing the endodontic cavity and found that the technique allows accurate preparation of the access cavity down to the apical third of the root. The study found that the differences between planned and prepared access cavities were minimal, with mean deviations ranging from 0.16 to 0.21 mm at the base of the drill and 0.17 to 0.47 mm at the tip. The average angular deviation was 1.81°. These results demonstrate a high level of accuracy for the Guided Endodontics technique.(1)

Moreover, the study of *Connert et al.* found that the accuracy of the method was sufficient, even for narrow roots such as mandibular incisors, since the average angular deviation was 1.59° and the average linear deviation from the apical target point was 0.12-0.34 mm. (18)

In the same way, in the laboratory study of *Zubizarreta-Macho et al.,* the use of computer-assisted navigation in the study groups enabled the successful identification of all planned root canals without any complications.(9)

Finally, the observational study of *Buchgreitz et al.* confirms the accuracy of the guides. In 50 consecutive clinical cases, the use of CBCT and optical surface scans for guided preparation of the access cavity, canal location and negotiation were shown to provide optimal or acceptable accuracy in single-rooted anterior teeth with filled pulp spaces. Further examination of the drill path method showed that even the worst result was considered clinically acceptable. (6)

However, this accuracy varies between teeth, the study by *Su Y et al.* showed that all coronal, apical, linear and angular deviations were significantly higher in group of molars compared to the other two groups (10)
Moreover, studies conducted in a laboratory setting have revealed that intraoral scanners have a higher level of accuracy when capturing partial-arch impressions as compared to complete-arch impressions.(10,19)

5.2.2 Conservation / resistance to fracture

Various studies have highlighted the success of guided endodontics in tooth conservation and its role in fracture resistance. (8,11,13,19)

Firstly, in his study *Kostunov et al.* shows significant differences in conservation between the conventional and guided techniques for the three different types of teeth.(19)

Ali et al. states that the use of the endodontic guide approach resulted in a significant improvement in the fracture resistance of the teeth, compared to the control group. This improved fracture resistance may be because the guided endodontic technique caused less damage to healthy tooth structure. (11)

Indeed *Loureiro et al.* explains in his study that preservation of enamel and dentin structure during endodontic treatment allows the tooth to better withstand functional forces and, when combined with appropriate disinfection measures, helps to ensure the success of the procedure. The use of guided endodontic access results in less loss of tooth structure in teeth with more complex morphology. There was no significant difference in the amount of

tooth tissue removed with conventional or guided endodontic access for mandibular incisors. However, in the maxillary molar group, guided endodontic access resulted in a greater amount of tooth tissue being retained. (8)

Finally, *Connert et al.* emphasizes that the access cavities created by the use of the guided endodontic approach were intended to preserve as much tooth substance as possible. The study found that tissue loss during guided endodontics is concentrated around the canal. In contrast, during manual endodontics, dentin loss occurs in all directions and can lead to unpredictable root destruction. The conventional approach is therefore likely to have a more negative impact on the internal structure of the tooth, its deformability and strength. Under these conditions, the use of guided endodontics, with its small burr diameter and apically extended access cavity preparations, can offer clear advantages for the stability of treated teeth.(13)

5.2.3 Comparison of conventional and guided methods

As regards conservation of the teeth, several articles highlight the fact that the access cavity with endodontic guides is more conservative than the traditional method.
Guided preparations were found to be 34 to 48% less invasive than traditional access cavities. (19) They prevent over-preparation compared to the traditional method and are more conservative. (2,12,13) It's allowed for more preservation of dentin compared to conventional method, particularly in the crowns, the peri cervical dentin, and the dentin in the coronal third of the canal.(3) However there was no significant difference in the amount of tooth tissue removed in the middle third and below of the canal. One possible explanation is that the volume of dentine removed in the middle third and apical third of the canal was not affected by the design of the endodontic access cavity. (3) This leads to an increase in fracture resistance compared to the traditional method. (11) Indeed, the preservation of tooth structure through a guided access preparation may have even greater biomechanical benefits. (12)
Finally, regarding accuracy, the traditional, freehand endodontic access cavity preparation is less accurate compared to computer-aided static and dynamic navigation systems. (9) Moreover guided endodontics was more effective than conventional methods in finding root

canals in calcified teeth, as evidenced by a higher success rate of 22 out of 24 teeth compared to 10 out of 24 using the conventional approach. (12)

5.2.4 Time and experience of operator

The use of endodontic guide result in a timesaving compared to the traditional method.(2,11,18) In fact, accessing calcified root canals with or without a dental microscope might be even more time consuming than the guide endodontic technic. (1) The time spent on the drill path itself was not systematically measured, however, a rough estimate would be less than 2 minutes. This is in line with the total average treatment time, including the preliminary planning, which was around 10 minutes. (18) However, it should be kept in mind that with guided root canal treatment, most of the time is spent on the digital analysis that occurs in the laboratory and not during the actual procedure. (6)

Moreover, the micro guided endodontics technique present is a user-independent method for reaching root canals.(1,13,18)

5.3 Disadvantages and limitations of the technique

5.3.1 Disadvantage during the production of the guide

The accuracy of endodontic cavity access directly depends on the design and manufacturing process of the surgical template. If there is any inaccuracy during the fabrication process, it may result in intraoperative complications.(9)

In fact, some errors in guide accuracy may be caused by radiographic inaccuracies. In fact, there are several challenges in producing an endodontic guide, including accurately measuring the root canal in STL files, particularly with regards to calcified canals, C-shaped canals, or when a second mesiobuccal canal is present in upper molars.(2)

In some instances, the root canal could not be seen on the CBCT due to the system's spatial resolution of 0.5 mm, which exceeded the diameter of these root canals. This could result in imprecision, and as per the STROBE checklist, this requires further consideration. (6)

Additionally, in a clinical setting, artifacts from highly radiopaque restorations on a CBCT scan may hinder the accuracy of the scan alignment.(11,12,19)

Errors can also occur during the intraoral scan. Indeed, the professional must be careful when performing this step because distortions or errors may occur and compromise the results. The quality of the impression must be checked during the adaptation test of the prototype guide in the mouth. If the fit is not perfect, it is necessary to repeat the printing and planning. (22) For patients using aligners, they must stop using the aligner after oral scanning and CBCT until guided endodontic treatment is performed. Otherwise, it may change the position of the teeth and make it impossible to use them. Similarly, new restorations should not be re-bonded to maintain the original configuration of the teeth. (22)

Finally, the printing of the guide can also be a source of error. It must be calibrated correctly. It is very important to use the original inputs specified by the manufacturer, with regular changes. After the printing, and the processing of the guide, it is important to establish the washing and hardening, in order to guarantee the dimensional stability of the guide. (22)

5.3.2 Disadvantage during the use of the guide

Firstly, one of the uncertainties can be caused by a bad insertion of the bur in the sleeve. For example, the use of the guide for anterior teeth preparation can be difficult as the head of the handpiece can become entangled with the guide on the incisal edge, requiring a specially designed long bur. When using a diamond bur, it's important to consider the angle between the guide and the handpiece head to ensure proper preparation at an appropriate angle.(2) Indeed the insertion of the bur is very important. If the bur is not placed exactly perpendicular to the guide's occlusal side, the resulting area could become distorted and over-prepared(2)

The second source of error can be due to the movement of the bur inside the sleeve.
Regarding implant-guided surgery, the notion of the intrinsic error of the surgical template refers to the mechanical inaccuracies resulting from the gap between the burr and cylinder, which may have an impact on the precision of the surgical template. (10)
Errors during the utilization of the endodontics guide are also partly due to this gap between the drill and the sleeve, which is necessary to prevent heat build-up during access

preparation. Indeed, this gap results in angle deviation due to horizontal movement of the bur.(1,12,19)

The clinical use of endodontic guides must also consider the potential harm that may be caused by rotational or torque forces from motor-driven instruments in delicate structures such as restorations, extensive cavities, and previous trauma. (19) Indeed, the problem of heat generation during drilling is a concern and due to the length of the drill, cooling is limited during the process. (19) However, the study of Zhang et al. show that the access cavity preparation performed with guided endodontics has low- temperature rise on the root surfaces. The mean root surface temperature rise of the guided endodontics group was the lowest (5.07 °C). (20)

Moreover, a concern existed regarding the durability and stability of 3D-printed guides. As they were printed using light-curable resin, there was a risk of both the guide and the teeth being damaged during access opening, leading to outcomes that deviate from the original design.(2)

It's also important to recognize that overly conservative access restrict the examination and cleaning of the pulp chamber and may negatively impact instrumentation effectiveness. Further clinical research is necessary to assess if guided access cavities have any adverse clinical effects. (8,19) However, in the study of Wang et Al., the average percentage of the non-instrumented canal area was not significantly different among the guide endodontic group and the control group. (3)

Finally, the error rate is not the same for all teeth in the arch. In fact, there are several clinical challenges that can hinder the success of guided endodontic procedures on molars, such as limited mouth opening, the size of the drill, and the thickness of the template. (10,18) Indeed, there is a higher degree of discrepancy in the posterior region compared to the anterior region. This discrepancy can result in inaccuracies in the planning process when compared to cone beam CT data, leading to difficulties in accessing the canals in the molars group through the 3D-printed template (10) A direct route to the target area is necessary, making it challenging to use in this region.(11,12)

5.3.3 Limitations of endodontics guides

CBCT technology has gained widespread use in various branches of dentistry, including endodontology. However, it still involves some radiation exposure to the patient, which raises medical ethics concerns and incurs additional cost. It is crucial to use CBCT imaging wisely to minimize concerns about radiation exposure. (1,2,18,19)

In addition, the expenditure of time needed for 'Guided Endodontics' including CBCT acquisition, intra-oral scanning, virtual planning and printing was long when compared to conventional root canal treatment. (1,18)

The additional cost including CBCT, intra-oral scan, software and fabrication of templates is also to be taken into in count (1,19) However compared to an implant, the total cost of the micro guided endodontics approach appears to be significantly lower, especially when root canal treatment is not possible or not successful. (18)

To finish, the potential drawback of this method is that it may not be suitable for use in curved root canals. Indeed, extending the drill path without considering the curvature could cause damage to the root. It is important to emphasize that the method has anatomical limitations, including not just the curvature of severely curved roots, but also the presence of radicular grooves, oval roots, or isthmuses.(12,19)

5.4 Future perspectives

5.4.1 Dynamic technique and sleeveless guide system

Various endodontic guidance systems have been introduced, including sleeveless guide system and a dynamic navigation system (DNS)(10)

The main advantage of the dynamic technique is the ability to adjust the direction of the access cavity in real time. This is achieved using stereoscopic cameras that track the position of optical reference markers, which helps guide the preparation process according

to the pre-planned angle, pathway, and depth. This results in improved visibility during procedures and helps minimize the risk of accidental damage to dental tissue. It is particularly helpful in situations where mouth opening is limited or when working on posterior teeth. (9)

However, operating a computer-aided dynamic navigation system requires a certain level of technical skill, hand-eye coordination, and manual dexterity, which involves a learning curve, to maintain the correct angle, pathway, and depth of the drill entry point and control the handpiece. (9,10)

The sleeveless guide system uses guiding rails and cylinders attached to the handpiece to guide the direction. This technique requires less space above the occlusal surface and provide better visibility then sleeve template, therefore, it could be used to solve the problem of the lack of vertical space in molar area. (10)

5.4.2 Improvement of the technique

In order to improve the precision of the guided access cavity preparation, it is important to decrease the intrinsic error by either lengthening the sleeve or minimizing the gap between the drill and sleeve.(1,12,20) One approach to achieving this could be transferring the drill path into the access cavity and extending the sleeve, as demonstrated in a case report using light-cured composite resin. (10)

In addition, accuracy error depending on the direction of the bur, to minimize this error, various methods were explored with the implant guide, including the use of a drill guide sleeve, inserting a metal tube into the hole, and creating a specific bur for the hole.(2)

Moreover, it would be beneficial to have a wider range of commercially available drills in terms of diameter and length, as this would allow for a more patient-focused approach. For example, in the posterior region, a drill system with varying lengths could accommodate for the limited space. (21)

To finish, in the future, magnet resonance imaging (MRI) could play a significant role in dentistry. This would eliminate the use of ionizing radiation, which is particularly important for children who have more sensitive tissues and organs.(21)

6. CONCLUSION

Following the elaboration of our study the null hypothesis, that there is no difference between CT and SEG regarding the accuracy and conservation of tooth structure, is rejected.

Indeed, all the studies presented have shown that the accuracy of SEG is acceptable and superior to the CT.

Furthermore, these studies show that SEG preserves more tissue than CT and does not interfere with the efficiency of instrumentation.

This technique is particularly useful in certain clinical situations including anomalous teeth, fibre post removal, dens evaginatus, access cavity preparations in the normal tooth, and micro-endodontic surgical procedures.

However, it has some drawbacks, such as increased radiation exposure, elevated costs, and more challenging pulp chamber and root canal debridement and visualization. Therefore, it is important to weigh the benefits and limitations of this approach carefully.

In order to further investigate this new technique, more studies would be useful, such as experimental in vivo studies.

7. BIBLIOGRAFIC REFERENCE

1. Zehnder MS, Connert T, Weiger R, Krastl G, Kühl S. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. Int Endod J. 2016 Oct 1;49(10):966–72.
2. Choi Y, Jeon WS, Cho JM, Jeong HG, Shin Y, Park W. Access opening guide produced using a 3D printer (AOG-3DP) as an effective tool in difficult cases for dental students. J Dent Educ. 2021 Oct 1;85(10):1640–5.
3. Wang D, Wang W, Li YJ, Wang YR, Hong T, Bai SZ, et al. The effects of endodontic access cavity design on dentine removal and effectiveness of canal instrumentation in maxillary molars. Int Endod J. 2021 Dec 1;54(12):2290–9.
4. Xia J, Wang W, Li Z, Lin B, Zhang Q, Jiang Q, et al. Impacts of contracted endodontic cavities compared to traditional endodontic cavities in premolars. BMC Oral Health. 2020 Sep 7;20(1).
5. Faus-Matoses V, Faus-Llácer V, Moradian T, Riad Deglow E, Ruiz-Sánchez C, Hamoud-Kharrat N, et al. Accuracy of Endodontic Access Cavities Performed Using an Augmented Reality Appliance: An In Vitro Study. Int J Environ Res Public Health. 2022 Sep 1;19(18).
6. 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. Int Endod J. 2019 May 1;52(5):559–68.
7. Casadei B de A, Lara-Mendes ST de O, Barbosa C de FM, Araújo CV, de Freitas CA, Machado VC, et al. Access to original canal trajectory after deviation and perforation with guided endodontic assistance. Australian Endodontic Journal. 2020 Apr 1;46(1):101–6.
8. Loureiro MAZ, Elias MRA, Capeletti LR, Silva JA, Siqueira PC, Chaves GS, et al. Guided Endodontics: Volume of Dental Tissue Removed by Guided Access Cavity Preparation—An Ex Vivo Study. J Endod. 2020 Dec 1;46(12):1907–12.
9. Zubizarreta-Macho Á, Muñoz A de P, Deglow ER, Agustín-Panadero R, Álvarez JM. Accuracy of computer-aided dynamic navigation compared to computer-aided static procedure for endodontic access cavities: An in vitro study. J Clin Med. 2020 Jan 1;9(1).
10. Su Y, Chen C, Lin C, Lee H, Chen K, Lin Y, et al. 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 1;21(1).

11. Ali A, Arslan H. Effectiveness of the static-guided endodontic technique for accessing the root canal through MTA and its effect on fracture strength. Clin Oral Investig. 2021 Apr 1;25(4):1989–95.
12. 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. Int Endod J. 2016 Aug 1;49(8):790–5.
13. Connert T, Krug R, Eggmann F, Emsermann I, ElAyouti A, Weiger R, et al. Guided Endodontics versus Conventional Access Cavity Preparation: A Comparative Study on Substance Loss Using 3-dimensional–printed Teeth. J Endod. 2019 Mar 1;45(3):327–31.
14. Torres A, Shaheen E, Lambrechts P, Politis C, Jacobs R. Microguided Endodontics: a case report of a maxillary lateral incisor with pulp canal obliteration and apical periodontitis. Int Endod J. 2019 Apr 1;52(4):540–9.
15. Ali A, Arslan H. Guided endodontics: a case report of maxillary lateral incisors with multiple dens invaginatus. Restor Dent Endod. 2019;44(4).
16. Byun C, Kim C, Cho S, Baek SH, Kim G, Kim SG, et al. Endodontic treatment of an anomalous anterior tooth with the aid of a 3-dimensional printed physical tooth model. J Endod. 2015 Jun 1;41(6):961–5.
17. Kim JE, Shim JS, Shin Y. A new minimally invasive guided endodontic microsurgery by cone beam computed tomography and 3-dimensional printing technology. Restor Dent Endod. 2019;44(3).
18. Connert T, Zehnder MS, Weiger R, Kühl S, Krastl G. Microguided Endodontics: Accuracy of a Miniaturized Technique for Apically Extended Access Cavity Preparation in Anterior Teeth. J Endod. 2017 May 1;43(5):787–90.
19. Kostunov J, Rammelsberg P, Klotz AL, Zenthöfer A, Schwindling FS. Minimization of Tooth Substance Removal in Normally Calcified Teeth Using Guided Endodontics: An In Vitro Pilot Study. J Endod. 2021 Feb 1;47(2):286–90.
20. Zhang C, Zhao X, Chen C, Wang J, Gu P, Ma J, et al. The accuracy of using guided endodontics in access cavity preparation and the temperature changes of root surface: An in vitro study. BMC Oral Health. 2022 Dec 1;22(1).
21. Connert T, Weiger R, Krastl G. Present status and future directions – Guided endodontics. Vol. 55, Int Endod J. 2022; p. 995–1002.

22. Fonseca Tavares WL, de Oliveira Murta Pedrosa N, Moreira RA, Braga T, de Carvalho Machado V, Ribeiro Sobrinho AP, et al. Limitations and Management of Static-guided Endodontics Failure. J Endod. 2022 Feb 1;48(2):273–9.