https://doi.org/10.54589/aol.38/3/195

Retrospective analysis of guided access technique in calcified canals using cone beam tomography and digital scanning

Bruna de Athayde Casadei[1], Alexandre Sigrist De Martin[1], Rina A Pelerine[1], Wayne Martins Nascimento[1], Daniel Guimarães Pedro Rocha[2], Carlos E Fontana[3], Vinicius de Carvalho Machado[1], Carolina Pessoa Stringheta[1], Ana G Limoeiro[4], Michel Klymus[4], Thais Machado de Carvalho Coutinho[5], Marilia Fagury Videira Marceliano-Alves[5,6,7], Karoline de Oliveira Vieira Clemente[8], Carlos E da Silveira Bueno[1]

1. *Instituto de Pesquisa São Leopoldo Mandic, Faculdade de Odontologia São Leopoldo Mandic, Campinas, SP, Brazil.*
2. *Pontificia Universidade Católica de Campinas, Departamento de Endodontia, Campinas, São Paulo, Brazil*
3. *Pontificia Universidade Católica de Campinas, Programa de Pós-Graduação em Ciências da Saúde,Campinas, São Paulo, Brazil*
4. *Universidade de São Paulo, Faculdade de Odontologia de Bauru, Departamento de Dentística, Endodontia e Materiais Dentários, Bauru, SP, Brazil*
5. *Universidade Iguaçu, Programa de Pós-Graduação em Odontologia, Nova Iguaçu, Rio de Janeiro, Brasil*
6. *Centro Universitário Maurício de Nassau (UNINASSAU), Rio de Janeiro, Brasil*
7. *Department of Dental Research Cell, Dr. D. Y. Patil Dental College and Hospital, Dr. D. Y. Patil Vidyapeeth, Pune 411018, India*
8. *Universidade UNILAGOS, Araruama, Brazil*

ABSTRACT

The endodontic treatment of teeth presenting with calcified pulp is associated with significant technical difficulties. ***Aim:*** *To evaluate the success rate of the guided access technique for root canals using cone beam computed tomography (CBCT) between 2019 and 2021.* ***Material and Method:*** *The study selected cases of anterior and posterior teeth with severe pulp calcification, totaling 100 teeth including 59 incisors, 2 canines, 8 premolars, and 31 molars. CBCT scans were performed for all patients, and a virtual burr path was planned on a computer screen to guide the drill to the beginning of the root canal. The virtual drill path was delineated based on axial and cross-sectional tomographic data, and a template was fabricated using Computer Numerical Control (CNC) technology. Success was determined by reaching the canal lumen without deviation from the original path.* ***Results:*** *The success rate of the guided access technique was 99.1%, with calcification diagnosed in 48.7% of cases. Clinical history revealed deep restoration and necrosis in 34.8% of cases, and trauma in 34.8%. In 65.2% of cases, an attempt was made before referral for guided access.* ***Conclusion:*** *The guided access technique demonstrated high success rates, particularly when appropriately indicated.* ***Clinical relevance:*** *Guided access technique provides a reliable option for managing calcified root canals, thereby improving treatment outcomes.*

Keywords: *guided endodontics - cone beam tomography - image guided surgery*

To cite: de Athayde Casadei B, De Martin AS, Pelerine RA, Nascimento WM, Guimarães Pedro Rocha D, Fontana CE, de Carvalho Machado V, Pessoa Stringheta C, da Silva Limoeiro AG, Klymus M, de Carvalho Coutinho TM, Videira Marceliano-Alves MF, de Oliveira Vieira Clemente K, da Silveira Bueno CE. Retrospective analysis of guided access technique in calcified canals using cone beam tomography and digital scanning. Acta Odontol Latinoam. 2025 Dec 30;38(3):195-201. https://doi.org/10.54589/aol.38/3/195

Corresponding Author:
Ana Grasiela Limoeiro,
grasielalimoeiro@gmail.com

Received: November 2024.
Accepted: October 2025.

Análise retrospectiva da técnica de acesso guiado em canais calcificados utilizando tomografia de feixe cônico e escaneamento digital

RESUMO

O tratamento endodôntico de dentes que apresentam polpa calcificada está associado a dificuldades técnicas significativas ***Objetivo:*** *Avaliar a taxa de sucesso da técnica de acesso guiado para canais radiculares usando tomografia computadorizada de feixe cônico (TCCB) entre 2019 e 2021.* ***Material e Método:*** *O estudo selecionou casos de dentes anteriores e posteriores com calcificação pulpar grave, totalizando 100 dentes, incluindo 59 incisivos, 2 caninos, 8 pré-molares e 31 molares. As varreduras de CBCT foram realizadas para todos os pacientes, e um caminho de broca virtual foi planejado em uma tela de computador para guiar a broca até o início do canal radicular. O caminho da broca virtual foi delineado com base em dados tomográficos axiais e transversais, e um molde foi fabricado usando a tecnologia de Controle Numérico Computadorizado (CNC). O sucesso foi determinado ao atingir o lúmen do canal sem desvio do caminho original.* ***Resultados:*** *A taxa de sucesso da técnica de acesso guiado foi de 99,1%, com calcificação diagnosticada em 48,7% dos casos. A história clínica revelou restauração profunda e necrose em 34,8% dos casos, e trauma em 34,8%. Em 65,2% dos casos, uma tentativa foi feita antes do encaminhamento para acesso guiado.* ***Conclusão:*** *A técnica de acesso guiado demonstrou altas taxas de sucesso, particularmente quando bem indicada. Relevância clínica: A técnica de acesso guiado fornece aos clínicos uma opção confiável para o gerenciamento de canais radiculares calcificados, melhorando assim os resultados do tratamento.*

Palavras-chave: *endodontia guiada em 3D - tomografia de feixe cônico - cirurgia guiada por imagem.*

INTRODUCTION

Endodontic treatment of teeth with calcified pulp poses significant technical challenges[1]. The obliteration of the pulp space, often leading to tertiary dentin formation due to caries progression[2] or in deep restorations[3], complicates access to root canals. In addition, trauma-induced obliteration can further exacerbate the situation, making it difficult to perform endodontic procedures[4] such as lateral dislocation, intrusion or avulsion[5-7]. While preventive root canal treatment is not recommended as a routine protocol for teeth with pulp obliteration[8], approximately 10% of cases may develop periapical changes necessitating endodontic intervention after 15 years[9].

Accessing and navigating calcified canals is technically complex, and errors such as deviation from the original path or instrument breakage are common, even with surgical microscopy[10]. Radiographic guidance alone may lead to errors, highlighting the need for advanced techniques[11,12].

The combination of CBCT and digital scanning offers a promising solution for establishing a guide to negotiate calcified root canals[13]. Case reports have demonstrated positive outcomes using this approach in both anterior and posterior teeth[14-17]. The aim of this study was to evaluate the efficacy of the guided access technique in negotiating calcified root canals using CBCT and digital scanning.

MATERIALS AND METHOD

Human teeth were used after securing approval from the Ethics Committee - Instituto de Pesquisas São Leopoldo Mandic (number: 396931200005374). This was a retrospective study that analyzed data from 115 clinical cases conducted between January 2019 and March 2021. To analyze the success rate of the procedure, the initial CBCT image of each case (iCAT; Imaging Sciences International, Hatfield, PA; FOV 5 × 5 cm; voxel size 0.125 mm) and the final radiograph obtained after endodontic treatment were evaluated. Success was defined as the clinician's ability to reach the canal lumen, thereby overcoming pulp calcification.

The professionals who performed the treatments were sent a questionnaire, created using the Google Forms® application (GoogleCorp, Version 2018, Mountain View, California, USA), with the following questions: "How long ago did you graduate?"; "Are you a specialist in endodontics?"; "Did you attempt to access the canal before using a guided endodontic approach?"; "If you attempted access, did you do so with or without an operating microscope?"; "What is the patient's gender?"; "How was the diagnosis of calcification made?"; "Did you successfully access the canal lumen?"

The sample size was calculated using the Epi Info™ software (Centers for Disease control and prevention, available from: https://www.cdc.gov/epiinfo/por/pt_index.html). The sample size of 115 participants enabled the success of the technique to be estimated with a sampling error of 1.7% and a confidence level of 95%. Descriptive and exploratory data analysis was performed using absolute and relative frequencies. Then, the prevalence of clinical history of teeth with pulp calcification, the forms of calcification diagnosis, and the success of the guided access technique were estimated with their respective 95% confidence intervals. All analyses were performed using Program R with a significance level of 5%.

The inclusion criterion for case selection was anterior or posterior tooth with severe pulp calcification. The teeth analyzed were 59 incisors, 2 canines, 8 premolars and 31 molars in which the dentist was unable to reach the lumen of the dental canal, and therefore referred them to Scanning Radiology to make the prototype template. Teeth with metal restorations that could cause imaging artifacts were excluded. A CBCT scan (I-CAT Imaging Sciences International, Inc., Hatfield, PA, USA) was performed on all patients. Based on software designed for implant dentistry (SIM Implant, Sirona Dental Systems, Leuven, Belgium), a virtual burr path with a diameter of 1.3 mm was planned on the computer screen from an incisal reference to the beginning of the radiographically visible root canal. The burr path was designed to reach the first visible part of the root canal using special alignment procedures. After adjusting the angulation of the virtual burr path, it was possible to avoid involvement of the incisal edge and still reach the root canal lumen. A virtual washer was superimposed on the virtual burr path for drill guidance. The axial and cross-sectional tomographic data were used to determine the location of the root canal. Based on this, the virtual drill path was constructed. The teeth were scanned on the surface (R700 Desktop - 3 Shape, Copenhagen, Denmark). The virtual surface models were merged with the CBCT volume,

creating a combined image with a 3D volume of the tooth including the virtual burr path. The template including the metal washer was fabricated using Computer Numerical Control (CNC) technology as SICAT Optiguide (SICAT, Bonn, Germany) based on the combination image. This technology provides higher accuracy. To achieve better stability, the adjacent teeth were included in the template. The drill axis was angled so that the extended drill tip reached the radiographically visible lumen of the root canal (Fig. 1).

After planning the drilling position, a virtual model was designed using the model designer of the Simplant software (Dentsply Sirona). A guide sleeve (outer diameter 3.0 mm, inner diameter 1.4 mm and length 8 mm) was fitted to the drill using a software tool and virtually added to the planning library before the model was created. Fixation washers were also created to stabilize the guide and prevent the drill from deviating from its trajectory created using tomographic planning. The virtual model was exported as an STL file and sent to a 3D printer (Objet Eden 260 V with FullCure 720; Stratasys Ltd, Minneapolis, MN). The washer was incorporated into the printed model to guide the drill during cavity preparation. The dentist followed the protocol for attaching the template and drilling with the drill for access. The success of the guided access technique was assessed by the ability to reach the canal lumen without deviation from the original path.

Statistical analysis

Descriptive and exploratory data analysis was carried out using absolute and relative frequencies. Prevalence rates were then estimated for the clinical histories of teeth with pulp calcification, the ways in which calcification was diagnosed and the success of the guided access technique, with the respective 95% confidence intervals. All the analyses were carried out using the R program, with a significance level of 5%.

RESULTS

The success of the guided access technique consists of reaching the lumen of the canal that the dentist was unable to reach during the first treatment, with or without magnification. Of the 115 cases analyzed, 99.1% were successful, with calcification diagnosed in 48.7% of cases (Table 1). Of the 115 cases of guided access technique for calcified canals analyzed, 70.4% were performed by professionals with more than 10 years' training, of whom 98.3% were endodontists (Fig. 2).

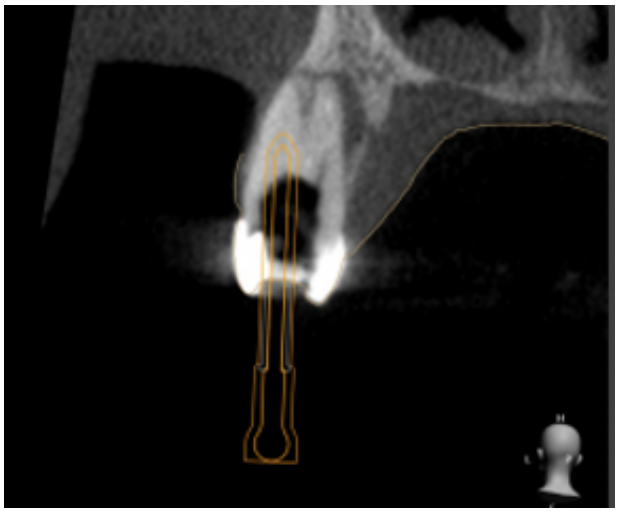

Fig. 1: CBCT with virtual simulation of the drill reaching the lumen of the canal.

Regarding the characteristics of the cases, 80.9% of the patients were female. Deep restoration and necrosis were observed in 34.8% of cases, while trauma was present in 34.8%. Most cases (65.2%) had attempted access before referral for guided access. It should also be noted that in 40.0% of cases, the specialists diagnosed calcification because they had unsuccessfully tried to access it with a microscope, and in one case (0.9%) the specialist unsuccessfully tried to access it with a microscope and cone beam tomography. In 12.2 % of the cases, the diagnosis was made because the dentist unsuccessfully attempted to access the canal without a microscope. Table 2 shows the prevalence with the respective 95% confidence intervals.

The one case of failure occurred in a tooth 21 (central incisor) where the template resulted in a deviation from the original canal course. This case of failure was performed by a professional with more than 10 years' training (Fig. 3).

DISCUSSION

Based on an analysis of 115 clinical cases across various tooth groups, the guided access technique demonstrated high accuracy in both anterior and posterior regions where pulp obliteration occurred due to calcification. This technique involves the integration of tomographic images, virtual planning, and scanning to create a guide that directs the entry of the low-rotation drill.

Table 1. Characteristics of clinical cases in which the guided access technique was used for calcified canals.

Variable	Category	Frequency (%)
Patient gender	Female	80.9
	Male	19.1
Tooth history	Deep restoration and necrosis	34.8
	Old trauma (more than one year)	32.2
	Caries with pulp contamination	8.7
	Complaint of darkening and the patient does not remember trauma in the region.	7.8
	Parafunctional habit	4.3
	Recent trauma (less than one year)	2.6
	Dentinogenesis imperfecta	1.7
	Referred with previous opening	1.7
	Periodontal pocket with pulp necrosis and periradicular abscess	0.9
	Deep caries, prosthetic purpose	0.9
	Symptomatic tooth. Patient does not remember history of trauma	0.9
	Orthodontic history	0.9
	Periapical lesion and symptomatology	0.9
	Tooth crown breakage	0.9
	Previous unsuccessful treatments and persistent pain	0.9
The way the calcification was diagnosed	Unsuccessfully attempted access using a microscope	40.0
	Initial radiographic exam	30.4
	Unsuccessfully attempted to access the canal without a microscope	12.2
	Another practitioner attempted unsuccessful access with microscope	7.8
	Other practitioners attempted unsuccessful access	4.4
	Deviation when attempting fiber abutment removal	2.6
	Tomography	1.7
	Unsuccessfully attempted access using microscopy and cone beam tomography	0.9
Success of the procedure	No	0.9
	Yes	99.1

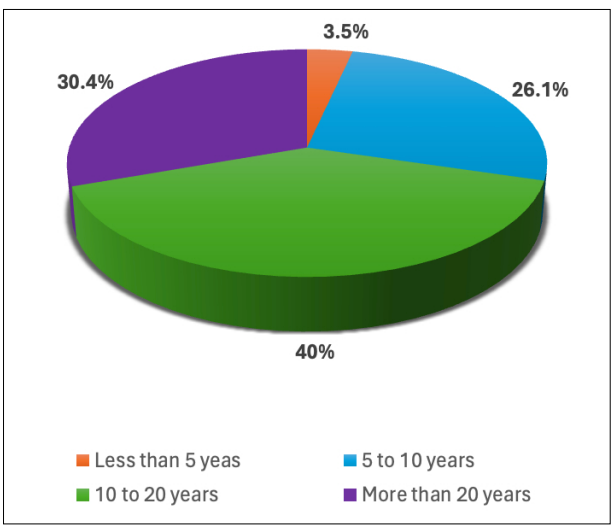

Fig. 2: Distribution of dental surgeons in the cases who underwent the procedure according to years' training.

The tooth structure loss caused by the drill is similar to the space created by a fiberglass post. In simulated teeth with calcification, conventional treatment resulted in greater structural loss compared to guided access localization[18-19]. Additionally, the conventional approach may lead to deviations and dislocations in various directions, thereby increasing the risk of accidents[20].

Advancements in technology, including CBCT, digital planning and 3D printing, have facilitated the introduction of guided endodontics. This study critically evaluated the clinical potential of the guided access technique and outlined the operative steps for safe implementation in treating complex endodontic cases. Primary indications for guided endodontics include accessing calcified root canals, navigating

Table 2. Prevalence and confidence intervals of clinical history in teeth with pulp calcification, form of calcification diagnosis and success of guided access technique procedure

Variable	Category	Prevalence (%)	Confidence intervals 95%
Clinical history of teeth	Deep restoration and necrosis	34.8	26.1% - 43.5%
	Trauma	34.8	26.1% - 43.5%
	Caries with pulp contamination	8.7	3.5% - 13.8%
The way the calcification was diagnosed	Attempted access without a microscope	16.5	9.7% - 23.3%
	Attempted access without a microscope without success	48.7	39.6% - 57.8%
	Initial radiographic exam	30.4	22.0% - 38.8%
Attempted access before guided access	Yes	65.2	56.5% - 73.9%
Success of the technique	Yes	99.1	97.4% - 100.0%

challenging anatomical areas, removing fiberglass posts, and managing teeth with developmental anomalies[21]. Guided endodontics has proven to be a precise, effective, safe, clinically applicable strategy, integrating technological resources and digital planning into endodontic practice[22].

Most of the dentists who participated in this study were specialists with over a decade's experience. They often attempted to gain access to the canal lumen using a surgical microscope before resorting to template fabrication at a radiology center. These findings underscore the significance of the technique in cases where traditional methods may have failed due to limitations in experience or technology. Guided endodontics enables safe access to the canal with reduced procedural time and minimal loss of hard tissue, regardless of the practitioner's expertise level[23].

Limitations of the guided technique include the need for direct, straight access to the canal lumen, as the drill is not curved. Accessing posterior molars can pose challenges, depending on factors such as mouth opening and the risk of microcrack formation due to drill overheating[12,17]. Furthermore, the time and cost involved in the process, including tomographic examination, scanning, case planning, and template fabrication, should be considered1[2]. While cavity preparation for guided access and guided surgery offers high accuracy and success rates, further research with larger patient cohorts is warranted to draw definitive conclusions[24]. Previous studies[25-28] indicate that guided endodontics offers advantages in terms of safety, speed and accessibility for less experienced practitioners. However, this technique also has limitations and the potential for iatrogenesis[29]. These limitations include inadequate fixation of the template to the bone, and inaccuracies in manual mesh fusion, which can lead to root perforations[18]. In addition, static guidance is limited to straight roots or segments of curved roots, requiring longer planning time and higher radiation exposure due to mandatory CBCT scans. Furthermore, the additional costs for CBCT and templates contribute to increased patient costs. Furthermore, the study did not differentiate between single-rooted and multi-rooted teeth, which could affect the results[30].

In conclusion, based on the sample analyzed in this study, the guided technique emerges as a reliable, accurate tool when appropriately indicated. Nonetheless, ongoing research and prospective clinical studies are essential to further substantiate the evidence supporting guided endodontic practice.

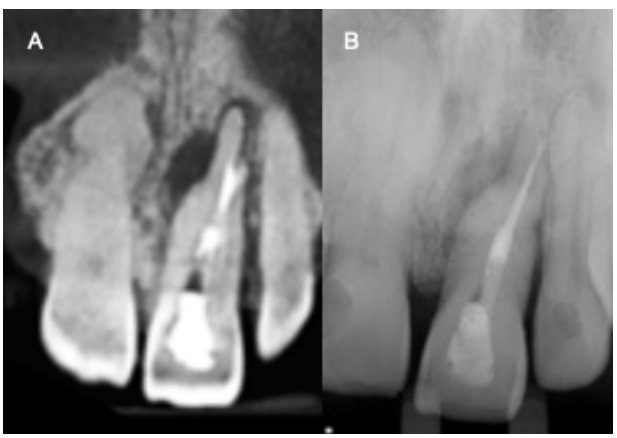

Fig. 3: Failure case: A) CBCT image and B) radiograph, note the deviation from the original canal course.

CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest regarding the research, authorship and/or publication of this article.

REFERENCES

1. McCabe PS, Dummer PM. Pulp canal obliteration: an endodontic diagnosis and treatment challenge. Int Endod J. 2012 Feb;45(2):177-97. https://doi.org/10.1111/j.1365-2591.2011.01963.x. Epub 2011 Oct 17. PMID: 21999441.
2. Bjørndal L, Darvann T. A light microscopic study of odontoblastic and non-odontoblastic cells involved in tertiary dentinogenesis in well-defined cavitated carious lesions. Caries Res. 1999;33(1):50-60. https://doi.org/10.1159/000016495. PMID: 9831780.
3. Fleig S, Attin T, Jungbluth H. Narrowing of the radicular pulp space in coronally restored teeth. Clin Oral Investig. 2017 May;21(4):1251-1257. https://doi.org/10.1007/s00784-016-1899-8 .Epub 2016 Jul 10. PMID: 27394425.
4. Cehreli ZC, Unverdi GE, Serdar Eymirli P. Ten-year follow up of previously traumatized immature permanent incisors sustaining second and third traumatic injuries after revascularization treatment: Case reports. Dent Traumatol. 2022 Dec;38(6):534-538. https://doi.org/10.1111/edt.12773. Epub 2022 Jul 8. PMID: 35766130.
5. Andreasen FM, Zhijie Y, Thomsen BL, Andersen PK. Occurrence of pulp canal obliteration after luxation injuries in the permanent dentition. Endod Dent Traumatol. 1987 Jun;3(3):103-15. https://doi.org/10.1111/j.1600-9657.1987.tb00611.x. PMID: 3476298.
6. Diangelis AJ, Andreasen JO, Ebeleseder KA, Kenny DJ, Trope M, Sigurdsson A, Andersson L, Bourguignon C, Flores MT, Hicks ML, Lenzi AR, Malmgren B, Moule AJ, Pohl Y, Tsukiboshi M. Guidelines for the Management of Traumatic Dental Injuries: 1. Fractures and Luxations of Permanent Teeth. Pediatr Dent. 2017 Sep 15;39(6):401-411. https://doi.org/10.1111/j.1600-9657.2011.01103.x. PMID: 29179382.
7. Flores MT, Andersson L, Andreasen JO, Bakland LK, Malmgren B, Barnett F, Bourguignon C, DiAngelis A, Hicks L, Sigurdsson A, Trope M, Tsukiboshi M, von Arx T; International Association of Dental Traumatology. Guidelines for the management of traumatic dental injuries. II. Avulsion of permanent teeth. Dent Traumatol. 2007 Jun;23(3):130-6. https://doi.org/10.1111/j.1600-9657.2007.00605.x. PMID: 17511833.
8. Robertson A, Andreasen FM, Bergenholtz G, Andreasen JO, Norén JG. Incidence of pulp necrosis subsequent to pulp canal obliteration from trauma of permanent incisors. J Endod. 1996 Oct;22(10):557-60. https://doi.org/10.1016/S0099-2399(96)80018-5. PMID: 9198446.
9. Jacobsen I, Kerekes K. Long-term prognosis of traumatized permanent anterior teeth showing calcifying processes in the pulp cavity. Scand J Dent Res. 1977 Nov;85(7):588-98. https://doi.org/10.1111/j.1600-0722.1977.tb02119.x. PMID: 272723.
10. Kiefner P, Connert T, ElAyouti A, Weiger R. Treatment of calcified root canals in elderly people: a clinical study about the accessibility, the time needed and the outcome with a three-year follow-up. Gerodontology. 2017 Jun;34(2):164-170. https://doi.org/10.1111/ger.12238. Epub 2016 Jun 14. PMID: 27296318.
11. 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;43(5):787-790. https://doi.org/10.1016/j.joen.2016.12.016. Epub 2017 Mar 11. PMID: 28292595.
12. 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;49(10):966-72. https://doi.org/10.1111/iej.12544. Epub 2015 Oct 3. PMID: 26353942.
13. 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;49(8):790-5. https://doi.org/10.1111/iej.12516. Epub 2015 Aug 22. PMID: 26201367.
14. Fonseca Tavares WL, de Carvalho Machado V, Oliveira Fonseca F, Canal Vasconcellos B, Cruz Guimarães L, Diniz Viana AC, Feitosa Henriques LC. Guided Endodontics in Complex Scenarios of Calcified Molars. Iran Endod J. 2020 Winter;15(1):50-56. https://doi.org/10.22037/iej.v15i1.26709. PMID: 36704320; PMCID: PMC9723215.
15. Casadei BA, Lara-Mendes STO, Barbosa CFM, Araújo CV, de Freitas CA, Machado VC, Santa-Rosa CC. Access to original canal trajectory after deviation and perforation with guided endodontic assistance. Aust Endod J. 2020 Apr;46(1):101-106. https://doi.org/10.1111/aej.12360. Epub 2019 Jul 2. PMID: 31267636.
16. Lara-Mendes STO, Barbosa CFM, Santa-Rosa CC, Machado VC. Guided Endodontic Access in Maxillary Molars Using Cone-beam Computed Tomography and Computer-aided Design/Computer-aided Manufacturing System: A Case Report. J Endod. 2018 May;44(5):875-879. https://doi.org/10.1016/j.joen.2018.02.009. Epub 2018 Mar 20. PMID: 29571910.
17. Connert T, Zehnder MS, Amato M, Weiger R, Kühl S, Krastl G. Microguided Endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique. Int Endod J. 2018 Feb;51(2):247-255. https://doi.org/10.1111/iej.12809. Epub 2017 Aug 3. PMID: 28665514.
18. Fonseca Tavares WL, de Oliveira Murta Pedrosa N, Moreira RA, Braga T, de Carvalho Machado V, Ribeiro Sobrinho AP, Amaral RR. Limitations and Management of Static-guided Endodontics Failure. J Endod. 2022 Feb;48(2):273-279. https://doi.org/10.1016/j.joen.2021.11.004. Epub 2021 Nov 18. PMID: 34801590.
19. Dąbrowski W, Puchalska W, Ziemlewski A, Ordyniec-Kwaśnica I. Guided Endodontics as a Personalized Tool for Complicated Clinical Cases. Int J Environ Res Public Health. 2022 Aug 12;19(16):9958. https://doi.org/10.3390/ijerph19169958. PMID: 36011600; PMCID: PMC9408804.
20. Connert T, Krug R, Eggmann F, Emsermann I, ElAyouti A, Weiger R, Kühl S, Krastl G. Guided Endodontics versus

Conventional Access Cavity Preparation: A Comparative Study on Substance Loss Using 3-dimensional-printed Teeth. J Endod. 2019 Mar;45(3):327-331. https://doi.org/10.1016/j.joen.2018.11.006. PMID: 30803541.

21. Santiago MC, Altoe MM, de Azevedo Mohamed CP, de Oliveira LA, Salles LP. Guided endodontic treatment in a region of limited mouth opening: a case report of mandibular molar mesial root canals with dystrophic calcification. BMC Oral Health. 2022 Feb 11;22(1):37. https://doi.org/10.1186/s12903-022-02067-8. PMID: 35148745; PMCID: PMC8832717.
22. Zargar N, Amiri M. Guided Endodontic Treatment for Calcified Central Incisor with Discoloration, a Conservative Approach Preserving Incisal Edge: A Case Report. Iran Endod J. 2023;18(4):259-263. https://doi.org/10.22037/iej.v18i4.42119. PMID: 37829836; PMCID: PMC10566003.
23. Vasudevan A, Sundar S, Surendran S, Natanasabapathy V. Tooth substance loss after incisal endodontic access and novel single-tooth template-guided endodontic access in three-dimensional printed resin incisors with simulated pulp canal calcification: A comparative in vitro study. J Conserv Dent. 2023 May-Jun;26(3):258-264. https://doi.org/10.4103/jcd.jcd_3_23. Epub 2023 May 16. PMID: 37398863; PMCID: PMC10309124.
24. Moreno-Rabié C, Torres A, Lambrechts P, Jacobs R. Clinical applications, accuracy and limitations of guided endodontics: a systematic review. Int Endod J. 2020 Feb;53(2):214-231. https://doi.org/10.1111/iej.13216. Epub 2019 Oct 23. PMID: 31520416.
25. Torres A, Lerut K, Lambrechts P, Jacobs R. Guided Endodontics: Use of a Sleeveless Guide System on an Upper Premolar with Pulp Canal Obliteration and Apical Periodontitis. J Endod. 2021 Jan;47(1):133-139. https://doi.org/10.1016/j.joen.2020.09.016. Epub 2020 Oct 9. PMID: 33045264.
26. Torres A, Dierickx M, Coucke W, Pedano MS, Lambrechts P, Jacobs R. In vitro study on the accuracy of sleeveless guided endodontics and treatment of a complex upper lateral incisor. J Dent. 2023 Apr;131:104466. https://doi.org/10.1016/j.jdent.2023.104466. Epub 2023 Feb 18. PMID: 36804580.
27. Torres A, Dierickx M, Coucke W, Pedano MS, Lambrechts P, Jacobs R. Ex-vivo and in-vivo validation of a novel measuring protocol for guided endodontics. J Dent. 2023 Aug;135:104566. https://doi.org/10.1016/j.jdent.2023.104566. Epub 2023 May 31. PMID: 37263407.
28. Todd R, Resnick S, Zicarelli T, Linenberg C, Donelson J, Boyd C. Template-guided endodontic access. J Am Dent Assoc. 2021 Jan;152(1):65-70. https://doi.org/10.1016/j.adaj.2020.07.025. Epub 2020 Nov 6. PMID: 33168140.
29. Fonseca Tavares WL, de Oliveira Murta Pedrosa N, Moreira RA, Braga T, de Carvalho Machado V, Ribeiro Sobrinho AP, Amaral RR. Limitations and Management of Static-guided Endodontics Failure. J Endod. 2022 Feb;48(2):273-279. https://doi.org/10.1016/j.joen.2021.11.004. Epub 2021 Nov 18. PMID: 34801590.
30. Connert T, Weiger R, Krastl G. Present status and future directions - Guided endodontics. Int Endod J. 2022 Oct;55 Suppl 4(Suppl 4):995-1002. https://doi.org/10.1111/iej.13687. Epub 2022 Feb 4. PMID: 35075661; PMCID: PMC9790195.