INTERNATIONAL DEVELOPMENT PLANNING REVIEW
ISSN:1474-6743 | E-ISSN:1478-3401
DOI-10.6084/m9.figshare.26076659

MANUSCRIPT GUIDED ENDODONTIC ACCESS CAVITY OF CALCIFIED TEETH. A SYSTEMATIC REVIEW

1- Dr. Sarah Ayman Barzanji
Consultant Endodontist
Ministry of National Guard Health Affairs Jeddah, Saudi Arabia

2- Awwadh Ahmed Alzahrani ,
BDS , king abdulaziz university, Jeddah, KSA

3- Ahmed Almotazbilla Shawly,
BDS , king abdulaziz university, Jeddah, KSA

4- Mohammed Saeed Alghamdi ,
BDS , King Abdulaziz University, Jeddah, KSA

5- Osama Kharsan Alghamdi ,
BDS , King Abdulaziz University, Jeddah, KSA

6- Ethar Khalid Alkindy,
BDS , King Abdulaziz University, Jeddah, KSA

7- Mohammed Faisal Alghamdi ,
BDS , King Abdulaziz University, Jeddah, KSA

8- Abdulrahman Abdulkhaleg Algarni,
BDS , king Abdulaziz University, Jeddah, KSA

9- Rahaf Abdulrhman Alshehri
Vision collage , Jeddah, KSA

Abstract:

The field of endodontics is both lucrative and demanding. Even the most skilled clinicians may find it difficult to negotiate, clean, and shape canals, especially if calcifications have obstructed them. It can take a long time and be difficult to get around these obstacles; occasionally, it is also impossible. Although they have had varying degrees of success, various strategies have been devised to help with this issue. This is a crucial issue since the outcome of endodontic therapy depends on the removal or reduction of bacterial impacts on periapical tissues. The aim of this systematic review was to compare the conventional freehand and guided endodontic approaches to access cavity preparation and canal localization seen in calcified pulp canals.

Our approach was to review relevant articles that specifically evaluated canal access in cases of obliteration due to calcification. The search was conducted from January 2016 to May 2023,

utilizing the following keywords and combinations: (guided endodontics) AND (access cavity) AND (pulp calcification) on PubMed and Google Scholar search engines. A total of 21 studies were included in the review after careful sorting and the exclusion of articles that did not meet the inclusion criteria. A PRISMA flowchart was used as the critical appraisal tool.

Results from this review have revealed the comparative advantage of guided technique over conventional freehand technique, with successes recorded in terms of lesser tooth tissue loss, reduced incidence of iatrogenic errors, and a faster clinical approach to navigating calcified canals. A significant limitation of the guided approach is the relative cost when compared to the conventional freehand approach due to the necessary usage of intraoral scanning and a cone beam CT. However, with the aid of guided endodontics, calcified root canals can be located and navigated more quickly and with substantially less tooth loss. There is, however, little literaturethat compares the quantitative success rates of the conventional freehand approach and the guided approach. More studies in this area will give a broader view and extensively explain the successes and limitations of each method.

INTRODUCTION

Pulp canal obliteration (PCO), also known as calcific metamorphosis (CM), is a complication following tooth trauma that has been linked to concussions and occurs in 15% to 40% of cases with subluxation injuries [1]. According to the American Association of Endodontics (AAE), PCO is the rapid deposition of hard tissue within the pulp space, frequently in response to trauma [2][22]. Additionally, it could develop as a result of carious lesions, coronal restorations, vital pulp treatment procedures, the apposition of secondary dentine over time in elderly individuals, or an unfavorable reaction to orthodontic forces [3].

Pulpal obliterated teeth typically have no symptoms and don't require any treatments beyond an annual checkup. Therefore, these presentations are frequently discovered incidentally as a result of clinical or radiological investigations [4].

The teeth look yellow clinically, with a darker hue and less translucency. Radiographically, there has either been a partial or complete loss of pulp canal space, with or without periapical pathosis [4]. There is general agreement that root canal therapy is not necessary unless pulpal or periapical pathosis is clearly visible on radiographs and clinically. As a result, treatment is delayed until symptoms are visible. Over time, calcified teeth may experience pulpal necrosis or periapical diseases, at which point a root canal procedure may be necessary. After a longer observation period, this is expected in up to 27% of the studied teeth with PCO [5].

Complete radiographic obliteration does not always imply that the pulp or canal space is absent; more often, a pulp canal space with pulp tissue is present; however, treatment is always complicated [4].Cases involving PCO are difficult; preparation of the access cavity and canal negotiation are crucial steps where problems and mishaps may happen [6]. The AAE rates teeth with PCO as having a high level of difficulty. Technical issues can result in endodontic failure by causing root perforation due to deviation from the initial path, irretrievable instrument fracture, incomplete instrumentation, bacterial persistence, and debris [7].

Because the operator does not notice the typical "drop-off" in the pulp chamber during access cavity preparation, perforation can result. These teeth may have been so severely compromised during tooth preparation to find the canal in the cervical region of the teeth that they would now be susceptible to root fracture in the future [4].

In the literature, several attempts to prevent these issues can be found. A study recommended that the access cavity be made near to or through the incisal edge to permit straight line access after 3–4 mm of penetration without locating the canal or that the bur be twisted to lie parallel to the long axis of the tooth [8]. The CEJ was employed by two studies [9][10] as a landmark to find the pulp chamber. At the level of the CEJ, the pulp chamber is always found in the middle of the tooth. The hue of the calcified pulp chamber was also employed. In comparison to the axial wall root dentine, it is darker and has a distinct appearance. This can be improved by identifying the minute color changes with the dental operating microscope [9].

Other techniques include using different burs and ultrasonic tips for the deep troughing necessary to locate and enter calcified pulp chambers and canals, dyes like methylene blue to locate the canal system under a microscope, using sodium hypochlorite through the "bubble" or "champagne" test, and taking radiographic images at various angles to maintain alignment and direction [4]. Magnifying glasses, microscopes, and CBCT are more recent innovations that canbe used for improved guidance, although it might be challenging for the operator—especially a novice—to interpret the CBCT pictures, develop a mental guide, and carry out the therapy manually at the same time [10].

A computer-assisted therapeutic strategy was created to localize calcified root canals in a minimally invasive manner, and the term "guided endodontics" was established in order to reduce the risk of technical errors and treatment time [5]. GE addresses the issues associated with conventional access cavities based on the utilization of computer technology and endodontic treatment planning. By designing a particular channel for root canal access and instrumentation, the risk of perforations and other iatrogenic issues is thereby decreased. It has been demonstrated that guided endodontics is less time-consuming when used for endodontic retreatments involving microsurgery [10].

Static guided endodontics (SGE) and dynamic guided endodontics (DGE) are the two forms of guided endodontics now used [10] According to recent research, guided endodontic access cavities are an effective and minimally invasive technique. The benefits of guided models and three-dimensional (3D) planning for identifying the root canal system exceed the method's high cost [11]. Various studies have reviewed the accuracy and efficiency of guided endodontics. This study aims to review the current application of both types of guided endodontic access cavities in the cases of PCO specifically and to identify their advantages and limitations over conventional access cavities in such cases [10].METHODOLOGY

Pulp canal obliteration cases are challenging; preparing the entry cavity and negotiating the canal are critical procedures where issues and mistakes may arise. The goal of this study is to review the research on the relative merits of the traditional freehand cavity access technique versus the guided approach.

Research Strategy

A search of literature was performed in September 2023 using PubMed and Google Scholar search engines. The search was conducted from January 2016 to May 2023, utilizing the following keywords and combinations:

((guided endodontics) AND (access cavity)) AND (pulp calcification).

The search was limited to studies published in English. The full search strategy is summarized, and for a comprehensive assessment, we also searched the reference lists of all the included articles to identify other studies that may be relevant to this review. A PRISMA flow chart was used as the critical appraisal tool.

The following inclusion and exclusion criteria were applied:

Inclusion criteria:

- English-published studies on guided endodontic access cavities for pulp canal obliteration
- Studies that are within the 7-year period
- Human-based studies

Exclusion criteria: Non-guided endodontic access cavity treatment for pulp canal obliteration

- Non-English studies
- Systematic review studies
- Animal and ex-vivo studies

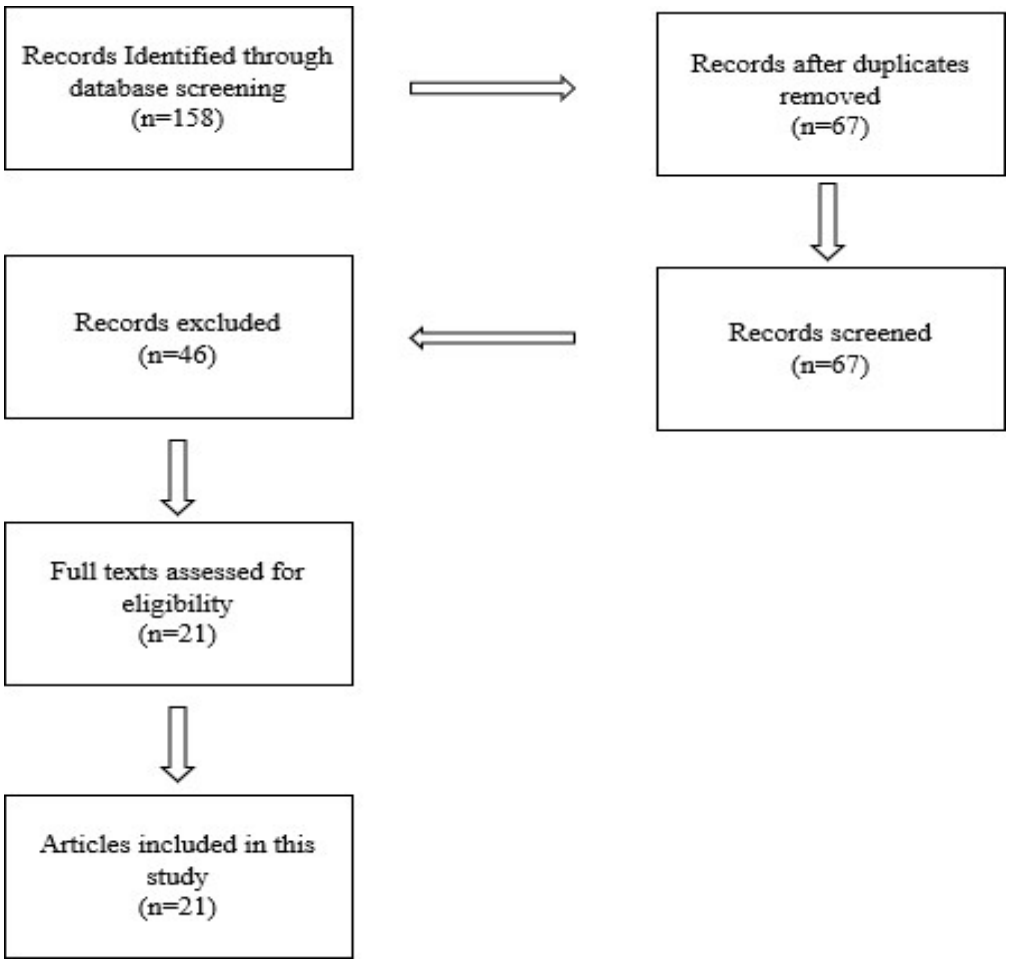
After screening and implementation of the eligibility criteria, 21 articles were included in total.

Data Extraction

Data extraction for the selected studies was based on the following factors:

- Citation (first author and publication year)

- Type of study/number of sampling participants
- Aim/approach



- Outcome

Fig 1: PRISMA Flow Chart

Limitations

1. Reduced in vivo studies that will objectively assess the methods of access cavity use

2. The guided approach is a recent innovation, and there is also limited research work done on it.

3. Quantitative analysis of the results was difficult to achieve due to the qualitative results of most articles included in this review.

RESULTS

Primary Outcome

The aim of this systematic review is to evaluate studies that used the application of guided endodontic access cavities in cases of pulp canal obliteration and then analyze the advantages and limitations of the different types of guided endodontic access cavities. Following the PRISMA selection process, 21 full articles were included in this systematic review.

Data Presentation

S/N	Citation	Type of study	Aim	Outcome
1.	Connert et al., 2019	Cohort study	To compare endodontic access cavities in teeth with calcified root canals with conventional and guided techniques	41.7% success rate for conventional technique and 91.7% for guided approach
2.	Todd et al., 2021	Case report	To assess the success of static guided endodontic access cavity	Successful root canal was done using 3D radiography with bypass of canal blockage with minimal tooth loss
3.	Goncalves et al, 2021	Case reports	To report the success of guided endodontic access	In the two cases presented, the use of

			cavity using intraoral scanning and Cone beam CT	guided endodontics allowed the preservation of a larger part of dental structure without occurrence of fracture and perforation
4.	Leontiev et al., 2022	Case Report	To present the technique of guided access cavity preparation by means of a miniaturized navigation system from imaging to clinical implementation	There was a successful use of the dynamic navigation system in access cavity preparation with minimal time use.
.	Pires et al., 2023	Cohort study	To evaluate the drilling path and dentin wear of two instruments during guided endodontic access cavity	There was no difference found in drilling path but the use of the guided access improved visualization and reduced loss of tooth structure

6.	Connert et al., 2021	Cohort Study	To evaluate substance loss and the time required for access cavity preparation (ACP) using the conventional freehand method (CONV) versus a miniaturized dynamic navigation system	Tooth substance loss was significantly lower with guided endodontic access than in conventional freehand
7.	Krastl et al., 2016	Case report	To present a new treatment approach for teeth with pulp canal calcification (PCC) which require root canal treatment.	The presented guided endodontic approach seems to be a safe, clinically feasible method to locate root canals and prevent root perforation in teeth with Pulp Canal Calcification.
8.	Torres et al., 2021	Case report	To present a novel guided endodontics technique using a sleeveless 3-dimensional- printed guide	This technique seems to be a promising alternative in comparison with the conventional guided endodontic guide

				design for the negotiation of pulp canal obliteration in cases in which vertical space is limited.
9.	Connert et al., 2018	Case report	To present a novel miniaturized and minimally invasive treatment approach for root canal localization in mandibular incisors with pulp canal calcification and apical periodontitis.	This case report demonstrates that minimally invasive and apically extended access cavities are feasible in mandibular incisors with this technique.
10.	Loureiro et al., 2021	Case report	To discuss the impact of new diagnostic and planning technologies on the resolution of a clinical case of an upper central incisor with lateral perforation, root canal calcification and apical periodontitis.	The treatment results were satisfactory at 6 months follow up

11.	Lara-Mendes et al., 2018	Case report	To describe a guided endodontic technique that facilitates access to root canals of molars presenting with pulp calcifications	The guided endodontic technique in maxillary molars was shown to be a fast, safe, and predictable therapy and can be regarded as an excellent option for the location of calcified root canals, avoiding failures in complex cases.
12.	Nabavi et al., 2022	Case report	To manage mandibular incisors with pulp canal obliteration using guided endodontics	With the use of a targeted 3D guide, a conservative access cavity was prepared to avoid unnecessary removal of tooth structure. The teeth were successfully treated endodontically.

13	Lara-Mendes et al., 2018	Case report	To describe an endodontic treatment technique performed through a new minimally invasive approach that leads to no tooth damage at the incisal edge and uses cone-beam computed tomographic (CBCT) imaging and 3-dimensional guides	The guided endodontic therapy optimized the treatment, having provided a conservative access with no tooth damage at the incisal edge in a safe and predictable way despite the presence of a severely calcified root canal.
14.	Krug et al., 2020	Case report	To report the outcome of guided endodontic treatment (GET) of a case of dentin dysplasia with pulp canal calcification (PCC) and apical periodontitis based on the use of a 3D-printed template	All root canals were rapidly and successfully located with the templates. At 1-year follow-up, clear signs of apical healing were present in all treated teeth.
15.	Torres et al., 2019	Case report	To describe a minimally invasive method to create a	A completely healed

				apical area of tooth

			3D-printed guide to gain access to obliterated root canals on the basis of CBCT data.	22 was visible after 6 months on periapical radiographs and small field of view CBCT.
16.	Tchorz et al., 2019	Case report	To describe the digital and clinical workflow of a guided endodontic access approach in a mandibular central incisor with pulp canal calcification	Localization of root canal was done successfully with less tooth loss
17.	Maia et al., 2019	Case report	To report the localization of calcified root canals of 1 molar and 2 premolars using guided endodontics	12-month clinical follow-up visits showed the effectiveness of the guided endodontic procedures.
18.	Dianat et al., 2021	Case report	To report the use of dynamic navigation system to access a partially calcified canal	Canal localization was successfully done using dynamic navigation system

19.	Wu et al., 2022	Case reports	To describe in detail the use, advantages, disadvantages, and limitations of a novel	The findings in these cases demonstrate that dynamic
			dynamic navigation system in 2 cases with severely calcified canals.	navigation system is a promising technique for locating calcified root canals.
20.	Ambu et al., 2023	Case series	To evaluate the precision of the guided endodontic technique applied to calcified canals in anterior teeth in relation to demographic and dental variables.	The guided endodontic technique applied to PCO did not cause iatrogenic errors, such as perforations,

21.	Santiago et al., 2022	Case report	To report the computer- Aided-Design and Manufacturing (CAD-CAM) workflow, the innovative strategies for the template ideation, and the guided endodontic treatment of a mandibular molar with dystrophic calcification in the mesial root canals.	The guided endodontic represents a personalized technique that provides security, reduced risks of root perforation, and a significant decrease of the working time to access obliterated root canals even in the mesial root canal
				of mandibular molars, a region of limited mouth opening.

DISCUSSION

The aim of this systematic review is to evaluate the comparative advantages and limitations of the types of guided endodontic access cavities over conventional freehand access cavities as well as identify the current application of the types of guided endodontic access cavities. Results from this review have shown a greater advantage of guided endodontic access cavities over conventional ones, with evidence based more on qualitative assessment than qualitative evaluation. A study, however, quantified the success rate of guided endodontic access cavities to be 91.7% and conventional freehand access cavities to be 41.7%. In the same study, the average time used for treatment was 21.8 minutes for conventional freehand and 11.3 minutes for the

guided endodontics technique. The study also emphasized that the guided approach was not influenced by operator experience [14].

Literature has also shown that the guided endodontic access cavity has a better comparative advantage in terms of minimal tooth loss, faster canal access, and lesser risks of iatrogenic errors such as perforations [18]. Important guiding elements are, however, absent in the case of a guided approach, including anatomical landmarks, differences in dentin quality, and normal and pathological coloration. For instance, a calcified root canal can be distinguished by its gray, transparent portion and the black tertiary dentin surrounding it. By providing this more information, skilled endodontists can use a conventional approach to find root canals. According to the findings of the current investigation, an expert was able to precisely pinpoint root canal orifices using "road mapping"[9]. However, traditional conventional pulp canal calcification tooth treatment comes with a lot of difficulties. According to a study, failure rates in these circumstances are 20% due to perforation [18]. 20% failure rates were also reported by anotherstudy, despite the fact that other studies showed that skilled specialists may reach success rates of 89% [20]. A study also evaluated the difficulties faced by experts while routinely attempting to access cavity preparation and canal localization in calcified root canals using the conventional freehand technique, which was shown to promote excessive wear of dental tissue and an increased risk of tooth fracture. In a case of failed conventional freehand technique, it has been shown that switching to a guided approach helps to reduce the risks associated with the complications seen in the conventional freehand technique. The cost of a guided approach in such cases is also seen as cost-effective [11]. However, the comparative cost of guided endodontic technique was seen to be higher, especially because of the need for a cone-beam CT scan and intraoral scanning [21].

The guided access cavity approach has also been seen to be applied in different clinical scenarios, such as cases of dentinal dysplasia, apical periodontitis, and pulp canal calcification. In cases of root canal therapy in mandibular incisors, guided access has proven to be more accurate and easier to navigate, especially when the tooth canals are calcified. This is made possible by the use of miniaturized instruments with a diameter of about 0.85mm. Treatment in these small and natural canals can be difficult even with the best experience and skill; however, the use of guided endodontics has made this easy and straightforward [14]. Guided endodontics has proven itself as a reliable alternative to traditional endodontic therapy in recent years. Guided endodontics is still viewed as a specialized application that is primarily employed by endodontic specialists, despite the fact that it has acquired widespread attention and diffusion in the field of endodontics. The inability to employ a guided approach in the posterior region and in teeth with weak roots are drawbacks, along with increased radiation exposure and more expenses related tothe design and creation of a template. Recent technological developments, such as narrower drills for precision preparation of thin roots, have, however, solved some of these issues.

Additionally, the better therapeutic success rates linked with cone beam CT justify the additional radiation exposure, and recent changes to the guided endodontic method have shown growing success in the treatment of root canals in the posterior region or in patients with reduced mouth opening [22]. In order to effectively carry out guided endodontics, planning is important, and this can be made possible by the use of 3D printing. A crucial element is how the directions are printed. Correct calibration is required. The use of only the original, manufacturer-specified

entries with frequent updates is essential. After printing, the guide will undergo post-treatment procedures, including washing and curing, which are crucial for the stabilization of the guide's dimensions. As shown in a study, low-quality pictures, sections with a thickness greater than 1 mm, and inaccurate threshold values can all compromise guided endodontic planning and cause deviations. The likelihood of failure increases when the CBCT shows no root canal space at all. The position of the bur in contact with the root canal's visible lumen will essentially be planned by the specialist. In rare instances, the calcification process may be so extreme that it is difficult to tell. In some circumstances, the operator must avoid inserting the instrument past the 3D planning's boundaries and must implement additional measures to improve root canal disinfection [12]. The increased accessibility of CAD/CAM technologies, which in turn has resulted in price decreases and decreased treatment costs for guided access cavities, has also increased the relevance of guided approaches. The adoption of 3D printers by guided endodontics also resulted in cheaper costs with enough accuracy [11].References

1. Oginni AO, Adekoya-Sofowora CA (2007) Pulpal sequelae after trauma to anterior teeth among adult Nigerian dental patients. BMC Oral Health 7, 11–5.
2. Natanasabapathy, Velmurugan & Sundar, Sathish & Saumya-Rajesh, Parashar & Kasabwala, Kinnari & Shilpa-Jain, DP & Sarathy, Sarath & Prabakaran, Keerthana & Haritha, JS & Bjørndal, Lars. (2021). Endodontic management of pulp canal obliteration using a new single-tooth template: A case series. Indian Journal of Dental Research. 32. 528. 10.4103/ijdr.IJDR_485_20.
3. Torres, A. & Dierickx, M. & Coucke, W. & Pedano, Mariano & Lambrechts, P. & Jacobs, R.. (2023). In vitro study on the accuracy of sleeveless guided endodontics and treatment of a complex upper lateral incisor. Journal of Dentistry. 131. 104466. 10.1016/j.jdent.2023.104466.
4. P.S. McCabe, P.M. Dummer, Pulp canal obliteration: an endodontic diagnosis and treatment challenge, Int. Endod. J 45 (2) (2012) 177–197.
5. Connert, Thomas & Weiger, Roland & Krastl, Gabriel. (2022). Present status and future directions - Guided endodontics. International Endodontic Journal. 55. 10.1111/iej.13687.
6. A.Chaniotis and R. Ordinola-Zapata, “Present status and future directions: Management of curved and calcified root canals,” *International Endodontic Journal*, vol. 55, no. S3. John Wiley and Sons Inc, pp. 656–684, May 01, 2022. doi: 10.1111/iej.13685.
7. Tavares, Warley & Pedrosa, Natália & Moreira, Raphael & Braga, Tiago & Machado, Vinícius & Sobrinho, Antônio & Amaral, Rodrigo. (2021). Limitations and Management of Static-Guided Endodontics Failure. Journal of Endodontics. 48. 10.1016/j.joen.2021.11.004.Amir FA, Gutmann JL, Witherspoon DE (2001) Calcific metamorphosis: a challenge in endodontic diagnosis and treatment. Quintessence International 32, 447–55.
8. Krasner P, Rankow HJ (2004) Anatomy of the pulp chamber floor. Journal of Endodontics 30, 5–16
9. K. Kulinkovych-Levchuk, M. P. Pecci-Lloret, P. Castelo-Baz, M. R. Pecci-Lloret, and R. E. Oñate-Sánchez, “Guided Endodontics: A Literature Review,” *International Journal of Environmental Research and Public Health*, vol. 19, no. 21. MDPI, Nov. 01, 2022. doi: 10.3390/ijerph192113900.
10. Krastl G. Zehnder M.S. Connert T.et al.Guided endodontics: a novel treatment approach

for teeth with pulp canal calcification and apical pathology. *Dent Traumatol.* 2016; 32: 240-246

11. Amir FA, Gutmann JL, Witherspoon DE. Calcific metamorphosis: a challenge in endodontic diagnosis and treatment. Quintessence Int 2002; 1: 61–69.
12. American Association of Endodontists. AAE Endodontic Case Difficulty Assessment and Referral. Endodontics 2005 Spring/Summer: 1-7
13. Connert T, Krug R, Eggmann F, et al. Guided Endodontics versus Conventional Access Cavity Preparation: A Comparative Study on Substance Loss Using 3-dimensional-printed Teeth. *J Endod*. 2019;45(3):327-331. doi:10.1016/j.joen.2018.11.006
14. Maia LM, de Carvalho Machado V, da Silva NRFA, et al. Case Reports in Maxillary Posterior Teeth by Guided Endodontic Access [published correction appears in J Endod. 2019 May;45(5):659]. *J Endod*. 2019;45(2):214-218. doi:10.1016/j.joen.2018.11.008Zehnder 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;49(10):966-972. doi:10.1111/iej.12544
15. Hildebrand, H., Leontiev, W., Krastl, G. *et al.* Guided endodontics versus conventional access cavity preparation: an ex vivo comparative study of substance loss. *BMC Oral Health* **23**, 713 (2023). https://doi.org/10.1186/s12903-023-03436-7
16. Tchorz, J. P., Wrbas, K. T., & Hellwig, E. (2019). Guided endodontic access of a calcified mandibular central incisor using a software-based three-dimensional treatment plan. *International journal of computerized dentistry*, *22*(3), 273–281.
17. KVINNSLAND I, OSWALD RJ, HALSE A, GRØNNINGSÆTER AG. A clinical and roentgenological study of 55 cases of root perforation. Int Endod J. 1989;22:75–84. https://doi.org/10.1111/j.1365-2591.1989.tb00509.x.
18. 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;34:164–70. https://doi.org/10.1111/ger.12238.
19. Gonçalves, W. F., Garcia, L. D. F. R., Vieira-Schuldt, D. P., Bortoluzzi, E. A., Dias-Júnior, L. C. L., & Teixeira, C. D. S. (2021). Guided Endodontics in Root Canals with Complex Access: Two Case Reports. *Brazilian dental journal*, *32*(6), 115–123. https://doi.org/10.1590/0103-6440202104537
20. Buchgreitz J, Buchgreitz M, Bjørndal L. Guided Endodontics modified for treating molars by using an Intracoronal Guide technique. J Endod. 2019;45:818–23. https://doi.org/10.1016/j.joen.2019.03.010Loureiro, M. A. Z., Silva, J. A., Chaves, G. S., Capeletti, L. R., Estrela, C., & Decurcio,

D. A. (2021). Guided endodontics: The impact of new technologies on complex case solution. *Australian endodontic journal : the journal of the Australian Society of Endodontology Inc*, *47*(3), 664–671. https://doi.org/10.1111/aej.12498

21. Todd, R., Resnick, S., Zicarelli, T., Linenberg, C., Donelson, J., & Boyd, C. (2021). Template-guided endodontic access. *Journal of the American Dental Association (1939)*, *152*(1), 65–70. https://doi.org/10.1016/j.adaj.2020.07.025
22. Pires, C. R. F., Souza-Gabriel, A. E., Pelozo, L. L., Cruz-Filho, A. M., Sousa-Neto, M. D., & Silva, R. G. (2023). Guided endodontics of calcified canals: The drilling path of rotary systems and intracanal dentin wear. *Australian endodontic journal : the journal of the Australian Society of Endodontology Inc*, *49 Suppl 1*, 64–70. https://doi.org/10.1111/aej.12684
23. Connert, T., Leontiev, W., Dagassan-Berndt, D., Kühl, S., ElAyouti, A., Krug, R., Krastl, G., & Weiger, R. (2021). Real-Time Guided Endodontics with a Miniaturized Dynamic Navigation System Versus Conventional Freehand Endodontic Access Cavity Preparation: Substance Loss and Procedure Time. *Journal of endodontics*, *47*(10), 1651–1656. https://doi.org/10.1016/j.joen.2021.07.012
24. Torres, A., Lerut, K., Lambrechts, P., & Jacobs, R. (2021). Guided Endodontics: Use of a Sleeveless Guide System on an Upper Premolar with Pulp Canal Obliteration and Apical Periodontitis. *Journal of endodontics*, *47*(1), 133–139. https://doi.org/10.1016/j.joen.2020.09.016
25. Connert, T., Zehnder, M. S., Amato, M., Weiger, R., Kühl, S., & Krastl, G. (2018). Microguided Endodontics: a method to achieve minimally invasive access cavitypreparation and root canal location in mandibular incisors using a novel computer-guided technique. *International endodontic journal*, *51*(2), 247–255. https://doi.org/10.1111/iej.12809
26. Krug, R., Volland, J., Reich, S., Soliman, S., Connert, T., & Krastl, G. (2020). Guided endodontic treatment of multiple teeth with dentin dysplasia: a case report. *Head & face medicine*, *16*(1), 27. https://doi.org/10.1186/s13005-020-00240-4
27. Torres, A., Shaheen, E., Lambrechts, P., Politis, C., & Jacobs, R. (2019). Microguided Endodontics: a case report of a maxillary lateral incisor with pulp canal obliteration and apical periodontitis. *International endodontic journal*, *52*(4), 540–549. https://doi.org/10.1111/iej.13031
28. Dianat, O., Gupta, S., Price, J. B., & Mostoufi, B. (2021). Guided Endodontic Access in a Maxillary Molar Using a Dynamic Navigation System. *Journal of endodontics*, *47*(4), 658–662. https://doi.org/10.1016/j.joen.2020.09.019
29. Wu, M., Liu, M., Cheng, Y., Tang, W., Yan, P., & Jiang, H. (2022). Treatment of Pulp Canal Obliteration Using a Dynamic Navigation System: Two Case Reports. *Journal of endodontics*, *48*(11), 1441–1446. https://doi.org/10.1016/j.joen.2022.07.014
30. Ambu, E., Gori, B., Marruganti, C., Malvicini, G., Bordone, A., Giberti, L., Grandini, S., & Gaeta, C. (2023). Influence of Calcified Canals Localization on the Accuracy of Guided Endodontic Therapy: A Case Series Study. *Dentistry journal*, *11*(8), 183. https://doi.org/10.3390/dj11080183
31. Santiago, M. C., Altoe, M. M., de Azevedo Mohamed, C. P., de Oliveira, L. A., & Salles,

L. P. (2022). Guided endodontic treatment in a region of limited mouth opening: a casereport of mandibular molar mesial root canals with dystrophic calcification. *BMC oral health*, *22*(1), 37. https://doi.org/10.1186/s12903-022-02067-8