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CBCT-Based Morphological Assessment and Static-Guided Endodontics in Teeth with Complex Canal Anatomy: A Case Series

Evaluación Morfológica Basada en CBCT y Endodoncia Guiada Estática en Dientes con Anatomía Compleja del Sistema de Canales: Serie de Casos Clínicos

Ximena Cruz[1]; Daniela Matus[1,2,3]; Matías Oliva[1]; Sofía González[1,2,4]; Scarlette Hernández-Vigueras[5] & Pablo Betancourt[1,2,3]

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SUMMARY: Pulp canal obliteration (PCO) and complex root canal anatomy represent significant challenges in endodontics, increasing the risk of iatrogenic errors during canal location. Static guided endodontics (SGE) has emerged as a minimally invasive and predictable approach for managing such cases through three-dimensional digital planning. The aim of this case series was to describe the endodontic management of teeth with root canal calcification or limited access due to previous treatments using static guided endodontics. This case series describes the management of five clinical cases (six teeth) presenting with PCO or limited canal access due to complex retreatments. Preoperative planning was performed by merging cone-beam computed tomography (CBCT) (DICOM) and intraoral scanning (STL) data. Customized three-dimensional printed guides were fabricated to direct the bur along a predetermined pathway to achieve canal access. Root canals were successfully located and negotiated in all cases without iatrogenic complications. Guided access allowed precise and conservative dentin removal, facilitating canal instrumentation. In one case, two teeth were managed simultaneously using a single guide, demonstrating procedural efficiency. All treated teeth remained asymptomatic at the end of treatment and were referred for definitive rehabilitation. Static guided endodontics appears to be a safe, effective, and predictable technique for the management of teeth with PCO or complex access. Its use may enhance accuracy, reduce procedural errors, and promote minimally invasive approaches, potentially reducing operator-dependent variability. Further prospective clinical studies are required to validate these findings.

KEY WORDS: Guided Endodontics; Cone-Beam Computed Tomography; Dental Pulp Calcification; Root Canal Therapy; Computer-Aided Design.

INTRODUCTION

Pulp canal obliteration (PCO) is one of the most significant technical challenges in contemporary endodontics. Characterized by the excessive deposition of tertiary dentin or dystrophic calcification of the pulp space, this condition significantly increases the complexity of orthograde treatment (Krastl *et al*., 2016; Connert *et al*., 2022; Kulinkovych-Levchuk *et al*., 2022; Bansal *et al*., 2025). Conventional endodontic treatment in teeth with pulp canal obliteration is associated with higher complication rates and a less favorable prognosis (Fonseca Tavares *et al*., 2022; Bansal *et al*., 2025). Although operating microscopy improves canal localization, it often requires longer operative times and may result in significant loss of dental tissue, particularly in the cervical region (Connert *et al*., 2022; Shabnam *et al*., 2024; Bansal *et al*., 2025). This contrasts with minimally invasive endodontic principles, which emphasize preservation of tooth structure, especially pericervical dentin due to its key role in stress distribution and fracture resistance (Connert *et al*., 2022).

Static guided endodontics (SGE) has emerged as an alternative for teeth with PCO and pulp and/or periapical pathology, reducing iatrogenic errors such as perforations, deviations, and excessive tissue loss through precise three-dimensional digital planning (Krastl *et al*., 2016; Shabnam *et al*., 2024; Nabavi *et al*., 2025). This technique has two

[1] Endodontic Specialization Program, Faculty of Dentistry, Universidad de La Frontera, Temuco, Chile.
[2] Center for Research in Dental Sciences (CICO), Endodontic Laboratory, Faculty of Dentistry, Universidad de La Frontera, Temuco, Chile.
[3] Department of Integral Adultos, Faculty of Dentistry, Universidad de La Frontera, Temuco, Chile
[4] Program of Master in Dental Science, Facultad de Odontología, Universidad de La Frontera, Temuco, Chile.
[5] Institute of Odontostomatology, Faculty of Medicine, Universidad Austral de Chile, Chile.
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main stages. In the digital planning phase, cone-beam computed tomography (CBCT) and intraoral scan data are integrated into software to virtually define the root canal access and design a custom 3D-printed guide (Fonseca Tavares *et al*., 2022; Hernández-Vigueras *et al*., 2022; Kulinkovych-Levchuk *et al*., 2022; Kasar *et al*., 2025; Nabavi *et al*., 2025). In the clinical phase, the guide is used to perform controlled and conservative milling; once the canal is located, it is removed and conventional endodontic treatment proceeds (Hernández-Vigueras *et al*., 2022; Kulinkovych-Levchuk *et al*., 2022; Kasar *et al*., 2025).

The aim of this case series was to describe the endodontic management of teeth with root canal calcification or limited access due to previous treatments using static guided endodontics.

MATERIAL AND METHOD

This study was conducted in accordance with the recommendations of the International Committee of Medical Journal Editors (ICMJE) and following the PRIDE (Preferred Reporting Items for Study Designs in Endodontics) guidelines for clinical case reports (PRICE). This study was approved by the Ethics Committee of Servicio de Salud Valdivia (approval code No. 309/2022). Five clinical cases are reported, corresponding to anterior and posterior teeth with difficult access to the root canal system, including obliterated canals and complex retreatments. All procedures were performed under absolute isolation, radiographic control, and using SGE. The clinical protocol included an initial clinical and radiographic evaluation, followed by CBCT and intraoral scanning. The images were evaluated

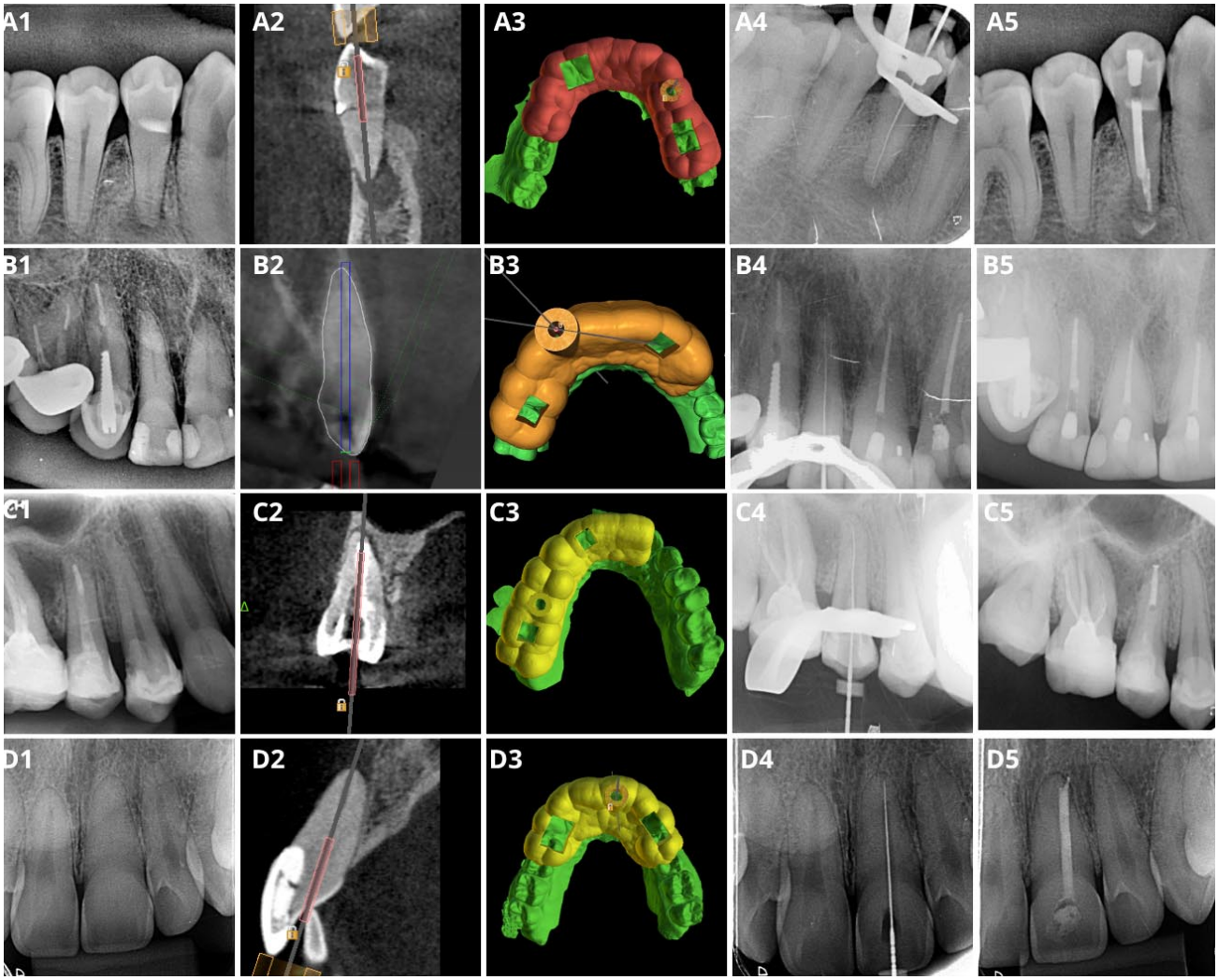


Fig 1. Representative workflow of static guided endodontics in Cases 1–4. Each case includes sequential images of diagnosis, digital planning, guided access, working length determination, and final obturation. (A1–A5) Case 1; (B1–B5) Case 2; (C1–C5) Case 3; (D1–D5) Case 4: initial periapical radiograph, CBCT-based drill planning, 3D guide design, working length radiograph, and final periapical radiograph after obturation.

by two experienced endodontists on a high-resolution monitor in a dimmed-light environment to ensure optimal visualization. Subsequently, digital planning was performed by merging the DICOM and STL files, enabling a precise access design. Based on this planning, customized guides were designed and manufactured using 3D printing. Instrumentation was carried out using mechanized systems, while obturation was performed using thermoplastic or combined techniques, employing epoxy sealer or bioceramic cement according to the specific characteristics of each case. All procedures were performed by two endodontic specialists with experience in guided endodontic techniques, except for Case 5, which was executed by a graduate student. All clinical procedures were performed in accordance with the

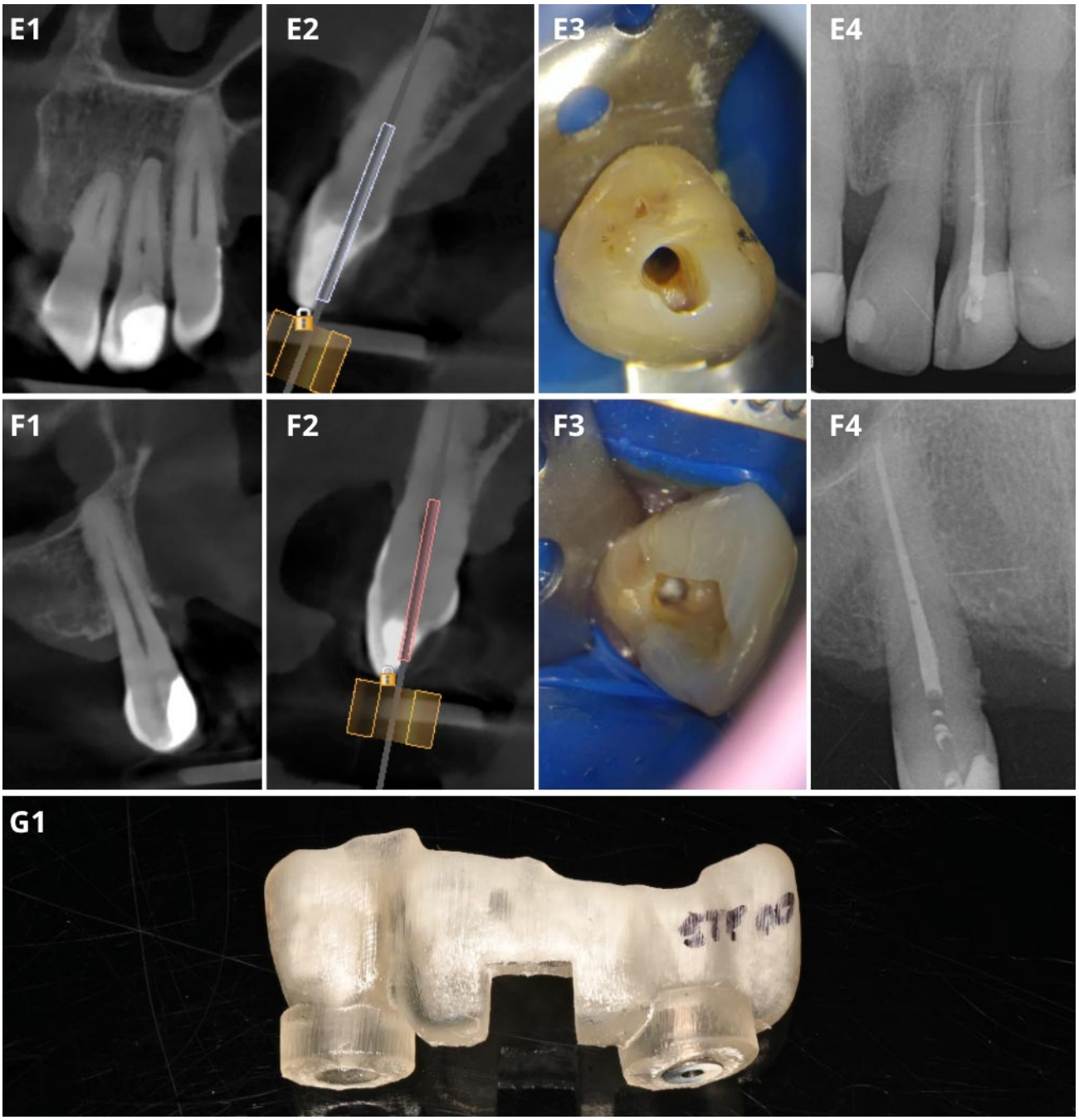


Fig 2. Static guided endodontic workflow for Case 5, showing the use of a single guide for two teeth. (E1–E4) Tooth 2.2: initial CBCT, drill path planning, guided clinical access, and final periapical radiograph after obturation. (F1–F4) Tooth 1.3: initial CBCT, digital planning, guided access, and postoperative pericapical radiograph. (G1) Clinical view of the static guide with dual access sleeves for both teeth.

Table I. Clinical, planning, and operative parameters of guided endodontic cases.

Case	Sex	Tooth	Diagnosis	CBCT unit	Software	Guided drill	Metal Sleeve	Guided access length (mm)	Mechanized instruments	Final Size
1	Male	4.4	Pulp necrosis with acute apical abscess	PAPAYA 3D+ (Genoray)	BlueSky Plan v4.7.5	STECO Ø1.0 mm × 21 mm	3.5 mm	16	WaveOne Gold (Dentsply Sirona)	45/.05
2	Female	1.2	Pulp necrosis with symptomatic apical periodontitis	Axeos (Dentsply Sirona)	coDiagnostiX	Ultradrill Ø0.9 mm × 28 mm	2.95 mm	14	WaveOne Gold (Dentsply Sirona)	35/.06
3	Female	1.5	Tooth with previously initiated therapy.	PAPAYA 3D+ (Genoray)	BlueSky Plan v4.7.5	Ultradrill Ø0.9 mm × 28 mm	2.95 mm	16	WaveOne Gold (Dentsply Sirona)	45/.05
4	Male	2.1	Pulp necrosis with asymptomatic apical periodontitis	NewTom GiANO HR (Cefla)	BlueSky Plan v4.7.5	Ultradrill Ø0.9 mm × 28 mm	2.95 mm	19	ZenFlex (Kerr)	40/.04
5	Female	2.2 / 1.3	Pulp necrosis with asymptomatic apical periodontitis (2.2) / indication for restoration (1.3)	Axeos (Dentsply Sirona)	BlueSky Plan v4.7.5	STECO Ø1.0 mm × 21 mm	3.5 mm	18 (2.2) / 17 (1.3)	Protaper Ultimate (2.2)/ Wave One Gold (1.3)	30/.04 (2.2) / 35/.06 (1.3)

principles of the Declaration of Helsinki. Written informed consent was obtained from all patients for the performance of the procedures and the publication of clinical information and images. The clinical workflow, including diagnostic imaging, digital planning, guide design, and treatment outcomes, is illustrated in Figure 1 (Cases 1–4) and Figure 2 (Case 5). The clinical details, planning, and operative parameters of the cases are summarized in Table I.

CASE 1

A 38-year-old male presented with pain in tooth 4.4. Clinical and radiographic findings, including canal obliteration and a periapical radiolucency, led to a diagnosis of pulp necrosis with acute apical abscess. Drainage was not required, and emergency trepanation was not attempted during the first session because the periapical radiograph showed near-total canal calcification, making the procedure highly risky. Due to the impossibility of performing trepanation during the emergency appointment, antibiotic therapy was prescribed (amoxicillin/clavulanic acid 875/125 mg, one tablet every 12 hours for 7 days).

CBCT (PAPAYA 3D+, Genoray, Seongnam, South Korea) and intraoral scanning (Primescan, Dentsply Sirona, Bensheim, Germany) were conducted. Digital planning was done using BlueSky Plan v4.7.5 (Blue Sky Bio, Grayslake, IL, USA). A customized static guide was designed, and a Steco drill (Steco-System-Technik GmbH & Co. KG, Hamburg, Germany), 1.0 mm in diameter and 21 mm in length with a 3.5 mm guide cylinder, was used. In the second session, after verifying the passive fit of the guide and administering local anesthesia, initial enamel reduction and guided access were performed to a depth of 16 mm, as determined by CBCT. Canal patency was confirmed with a #15 K-file, an electronic apex locator, and a periapical radiograph. Instrumentation was carried out using the WaveOne Gold 45/.05 reciprocating system (Dentsply Sirona, Ballaigues, Switzerland). Intracanal medication with calcium hydroxide was indicated. In the following session, the final irrigation protocol was completed with ultrasonic activation of 5 % NaOCl, followed by 18 % EDTA. Obturation was performed using the continuous wave technique with a thermoplasticized gutta-percha and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany).

CASE 2

A 73-year-old female was referred for endodontic treatment of tooth 1.2 with PCO, diagnosed with pulp necrosis and symptomatic apical periodontitis. CBCT (Axeos, Dentsply Sirona) and intraoral scanning (Primescan, Dentsply Sirona, Bensheim, Germany) were acquired. Digital planning was performed in coDiagnostiX (Dental Wings, Chemnitz, Germany). A customized static guide was designed, and an Ultradrill (Dentools, Bogotá, Colombia), 0.9 mm in diameter and 28 mm in length with a 2.95 mm guide cylinder, was used. Guided access was performed to a depth of 14 mm, as previously determined by the CBCT. Instrumentation was carried out using the WaveOne Gold 35/.06 reciprocating system (Dentsply Sirona, Ballaigues, Switzerland). The final irrigation protocol and obturation was performed following the protocol described in Case 1.

CASE 3

A 35-year-old female was referred for retreatment of tooth 1.5, which had been previously interrupted due to the impossibility of removing the filling material

in the cervical and middle thirds without a risk of perforation. The diagnosis was a tooth with previously initiated therapy. CBCT (PAPAYA 3D+, Genoray, Seongnam, South Korea) and intraoral scanning (Primescan, Dentsply Sirona, Bensheim, Germany) were acquired. Digital planning was performed using BlueSky Plan v4.7.5, and the static guide was designed using an Ultradrill (Dentools, Bogotá, Colombia), 0.9 mm × 28 mm with a 2.95 mm guide cylinder. Guided access was performed to a depth of 16 mm, reaching the gutta-percha in the apical third. After confirming patency, the endodontic nonsurgical retreatment was completed under absolute isolation. Instrumentation was carried out with WaveOne Gold 45/.05. Calcium hydroxide was placed as intracanal medication. In the final session, active irrigation was performed as described in case 1, and obturation was completed using lateral condensation in the apical third with epoxy sealer, supplemented in the middle and cervical thirds with bioceramic cement.

CASE 4

A 31-year-old male presented with coronal dyschromia in tooth 2.1 and notable PCO, diagnosed with pulp necrosis and asymptomatic apical periodontitis. CBCT (NewTom GiANO HR, Cefla, Imola, Italy) was acquired, and digital planning was performed using BlueSky Plan v4.7.5 (Blue Sky Bio, Grayslake, IL, USA). An Ultradrill (Dentools, Bogotá, Colombia) of 0.9 mm ¥ 28 mm with a 2.95 mm guide cylinder was used. After verifying the seating of the guide and administering infiltrative anesthesia, the access point was marked, and an initial enamel reduction (2 mm) was performed. Guided access was carried out to a depth of 19 mm, a depth determined by CBCT corresponding to the beginning of canal patency.

Instrumentation was completed using the ZenFlex rotary system (Kerr, Orange, CA, USA) up to size 40/.04, followed by active irrigation according to the protocol previously described in the earlier cases. Obturation was performed following the same protocol as in case 1.

CASE 5

A 72-year-old female was referred for endodontic treatment of teeth 2.2 and 1.3 prior to prosthetic rehabilitation. Tooth 2.2 showed no response to pulp sensibility tests and exhibited canal obliteration in the cervical and middle thirds, along with a periapical lesion; a diagnosis of pulp necrosis with symptomatic apical periodontitis was established.

Tooth 1.3 presented normal pulp and apical tissues but was included in the treatment due to rehabilitative requirements and the presence of physiological calcification in the cervical third. CBCT (Axeos, Dentsply Sirona, Bensheim, Germany) and intraoral scanning were acquired, and digital planning was performed in BlueSky Plan v4.7.5 (Blue Sky Bio, Grayslake, IL, USA), merging DICOM and STL files to design a static guide that included both teeth. Notably, a single static guide was designed to address both teeth simultaneously, optimizing the clinical workflow. A Steco drill (Steco-System-Technik GmbH & Co. KG, Hamburg, Germany) of 1.0 mm × 21 mm with a 3.5 mm guide cylinder was used. After verifying the seating of the guide and administering infiltrative anesthesia, the access point was marked, and an initial enamel reduction (2 mm) was performed. Guided access was carried out to 18 mm in tooth 2.2 and 17 mm in tooth 1.3, according to the CBCT planning. Instrumentation was performed using the Protaper Ultimate mechanized system up to size 30/.04 (Dentsply Sirona, Ballaigues, Switzerland) in tooth 2.2 and WaveOne Gold 35/.06 (Dentsply Sirona, Ballaigues, Switzerland) in tooth 1.3. Subsequently, the same final irrigation protocol and obturation technique as in case were applied.

DISCUSSION

There is consensus that endodontic treatment in teeth with PCO should only be indicated in the presence of clinical and/or radiographic signs of pulp or periapical pathology (Connert *et al*., 2018; Krastl *et al*., 2021; Ambu *et al*., 2023; Bansal *et al*., 2025). However, when this condition occurs, estimated in 1 % to 27 % of cases (Krastl *et al*., 2016; Connert *et al*., 2018), root canal localization becomes a significant clinical challenge. Conventional techniques are associated with an elevated risk of iatrogenic errors, including perforations or excessive wear, resulting in failure rates near 20 % (Fornara *et al*., 2024; Rahmatian *et al*., 2024; Shabnam *et al*., 2024; Bansal *et al*., 2025). In this context, SGE has emerged as a predictable and minimally invasive alternative for managing these complex cases. This technique allows for precise digital planning by integrating CBCT and intraoral scanning, facilitating targeted access to the root canal (Kulinkovych-Levchuk *et al*., 2022; Ambu *et al*., 2023).

The clinical cases presented in this study reinforce the available evidence, demonstrating that SGE is an effective and safe tool for canal localization in teeth with pulp obliteration. In the six treated teeth, five with PCO and one complex retreatment, it was possible to achieve canal localization and patency without iatrogenic complications. Furthermore, no significant post-operative discomfort was reported. Notably, Case 5 demonstrates the versatility of the digital workflow by using a single static guide to simultaneously manage two different teeth, thereby

optimizing clinical efficiency. These findings are consistent with previous reports highlighting high success rates and precision in the execution of guided access (Connert *et al*., 2018; Hernández-Vigueras *et al*., 2022; Mahendran *et al*., 2023; Fornara *et al*., 2024; Rahmatian *et al*., 2024; Fernández-Grisales *et al*., 2025; Kasar *et al*., 2025; Nabavi & Latifian, 2025; Nabavi *et al*., 2025). Nevertheless, it is important to acknowledge that the available evidence derives predominantly from in vitro studies, case series, and clinical reports, which limits the evidentiary strength and underscores the need for controlled clinical trials.

Beyond its clinical effectiveness, another relevant aspect of SGE is its relative independence from operator experience, as less experienced clinicians can achieve outcomes comparable to specialists in locating calcified canals, with minimal tooth structure loss and similar operating times (Connert *et al*., 2019; Fornara *et al*., 2024). Consistently, in this series, a case performed by a graduate student under supervision showed an equally successful outcome, suggesting that SGE may help standardize complex procedures and reduce operator variability.

From a technical standpoint, SGE allows for linear and controlled access through the use of small-diameter drills (0.75–1.2 mm), favoring the preservation of dental tissue and aligning with the principles of minimally invasive endodontics (Kulinkovych-Levchuk *et al*., 2022; Kasar *et al*., 2025). Furthermore, its implementation could decrease the reliance on advanced magnification, such as the operating microscope (Hernández-Vigueras *et al*., 2022; Rahmatian *et al*., 2024; Nabavi *et al*., 2025), which potentially expands its applicability in various clinical settings. However, this assertion should be interpreted with caution, as magnification continues to be a benchmark in contemporary endodontics.

Although guided endodontics has been proposed as a conservative and predictable technique for the management of calcified canals, the postoperative radiographs of Cases 1 and 4 revealed deviations from the original canal trajectory and an eccentric pattern of dentin removal. This finding may be related to case selection, as the remaining permeable portion of the canal was at the limit of the recommended indications for static guided endodontics. Several authors, including Fonseca Tavares *et al*. (2022) and Ribeiro *et al*. (2022), have suggested that the presence of an identifiable residual canal pathway favors more accurate guide orientation and reduces the risk of deviations; however, in both cases, the permeable canal segment represented less than one-third of the root length. These cases demonstrate that guided endodontics is not exempt from operative deviations and highlight the importance of meticulous planning, proper guide stabilization, and the use of conservative drills to minimize unnecessary dentin removal, particularly in teeth with reduced root thickness. This aspect is clinically relevant because excessive dentin removal in already compromised roots may negatively affect the long-term biomechanical behavior and fracture resistance of the tooth.

These considerations are especially relevant in trauma-associated pulp canal obliteration cases, such as Case 4, in which the indication for endodontic treatment was not based solely on canal obliteration or crown discoloration. Instead, the treatment decision resulted from a comprehensive clinical and radiographic assessment, including the absence of response to pulp sensibility tests, a history of dental trauma, progressive discoloration, and radiographic findings suggestive of pulpal necrosis associated with apical involvement. Although pulp canal obliteration following trauma is frequently associated with calcific metamorphosis and may remain asymptomatic for years, endodontic intervention becomes justified when clinical and radiographic signs suggest pulpal necrosis or apical pathosis. Therefore, the treatment decision in this case was based on the overall diagnostic assessment rather than on calcific obliteration alone.

On the other hand, SGE applications have expanded beyond canal localization to include post removal, guided periapical surgery, and retrograde obturation (Kulinkovych-Levchuk *et al*., 2022). This technological development, coupled with the increased longevity of the population and the complexity of restorative treatments, suggests that guided endodontics will play an increasingly relevant role in clinical practice. Accordingly, Case 3 illustrates the complexity of endodontic retreatment when the original canal anatomy has been previously modified. In this case, the previous operator discontinued the conventional retreatment procedure because of the hardness of the filling material located in the cervical and middle thirds, which significantly increased the risk of perforation. Under these conditions, conventional retreatment procedures, even when performed under magnification, may carry a substantial risk of creating a false pathway or causing iatrogenic perforation. Preoperative CBCT analysis proved essential to confirm the loss of the original anatomical guide and the severity of the obstruction. This assessment guided the decision to perform a static guided endodontic approach, which was considered the most predictable and conservative alternative for preserving the remaining peripheral dentin. Using this technique, a straight-line access of only 0.9 mm in diameter was achieved up to the apical third, minimizing the unnecessary dentin removal commonly associated with freehand techniques.

Despite its advantages, SGE presents significant limitations. Its implementation requires detailed preoperative planning and entails an increase in costs associated with the digital workflow and guide fabrication (Ishak *et al*., 2020; Torres *et al*., 2021; Hernández-Vigueras *et al*., 2022). Additionally, its use is primarily restricted to straight canals due to the linear nature of the access, which limits its applicability in complex anatomies. It can also be conditioned in patients with limited mouth opening, hindering guide insertion and clinical access (Ali *et al*., 2022; Connert *et al*., 2022; Fonseca Tavares *et al*., 2022; Hernández-Vigueras *et al*., 2022; Shabnam *et al*., 2024). In terms of precision, average deviations close to 0.46 mm at the drill tip have been reported (Krastl *et al*., 2016; Peña-Bengoa *et al*., 2023), which, although clinically acceptable, could imply inadvertent removal of dental tissue in cases of thin roots (Puri *et al*., 2024).

Finally, the limitations of this study must be recognized, including the small number of cases and its descriptive design, which preclude making generalizable inferences. Additionally, positive patient feedback regarding reduced anxiety and the absence of significant post-operative discomfort further supports the clinical utility of this workflow. Nevertheless, the results provide additional clinical evidence supporting the use of SGE as a safe and predictable alternative in the management of obliterated canals. Future studies with prospective designs and larger sample sizes will be needed to validate these findings and establish standardized clinical protocols.

CONCLUSION

Static guided endodontics is a predictable, safe, and minimally invasive approach for managing teeth with pulp canal obliteration. It enables precise canal localization while preserving tooth structure and reducing iatrogenic risks. However, careful case selection is required, considering the anatomical and technical limitations. Further prospective studies with long-term follow-up are needed.

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Conflict of interest. The authors declare no conflicts of interest.

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RESUMEN: La obliteración del canal pulpar (PCO) y la anatomía radicular compleja representan desafíos significativos en endodoncia, incrementando el riesgo de errores iatrogénicos durante la localización del conducto. La endodoncia guiada estática (EGE) ha surgido como un enfoque mínimamente invasivo y predecible para el manejo de estos casos mediante planificación digital tridimensional. Esta serie de casos describe el manejo de cinco casos clínicos (seis dientes) con PCO o acceso limitado al conducto debido a retratamientos complejos. La planificación preoperatoria se realizó mediante la fusión de datos de tomografía computarizada de haz cónico (CBCT) (DICOM) y escaneo intraoral (STL). Se fabricaron guías personalizadas impresas en tres dimensiones para dirigir la fresa a lo largo de una trayectoria previamente determinada y lograr el acceso al canal. En todos los casos, los canales radiculares fueron localizados y permeabilizados exitosamente sin complicaciones iatrogénicas. El acceso guiado permitió una remoción precisa y conservadora de dentina, facilitando la instrumentación. En un caso, dos dientes fueron tratados simultáneamente utilizando una sola guía, demostrando eficiencia del procedimiento. Todos los dientes tratados se mantuvieron asintomáticos al finalizar el tratamiento y fueron derivados para rehabilitación definitiva. La endodoncia guiada estática parece ser una técnica segura, efectiva y predecible para el manejo de dientes con PCO o acceso complejo. Su uso puede mejorar la precisión, reducir errores operatorios y favorecer enfoques mínimamente invasivos, disminuyendo potencialmente la variabilidad dependiente del operador. Se requieren estudios clínicos prospectivos para validar estos hallazgos.

PALABRAS CLAVE: Endodoncia guiada; Tomografía computarizada de haz cónico; Calcificación pulpar; Tratamiento de conductos radiculares; Diseño asistido por computadora.

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Corresponding author:
Pablo Betancourt DDS, MSc, PhD
Associate Professor
Centro de investigación en Ciencias Odontológicas
Universidad de La Frontera
Avenida Francisco Salazar 01145
Temuco
CHILE

Email: pablo.betancourt@ufrontera.cl

Orcid: https://orcid.org/0000-0002-9903-2920