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Effective Management of Calcified Root Canals Using Static-guided Access: A Case Series

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ABSTRACT

Root canal calcification poses a substantial challenge in endodontic practice and may lead to treatment failure. The difficulty lies in accessing, penetrating, and negotiating these canals. This article reports on a series of calcified root canals successfully treated using static-guided endodontics. Eleven cases of calcified root canals were treated by the same endodontist using static-guided endodontics. The sample encompassed four tooth types including a premolar with two canals, effectively managed using two templates (drill guides). Guided endodontic treatment was based on evidence of calcified root canals diagnosed with clinical, radiographic, and cone beam computed tomography (CBCT) findings. A high-resolution CBCT and an intraoral scan were used for virtual cavity planning. The CBCT and intraoral scan were superimposed, and virtual sleeves were accurately placed to avoid drilling deviation. Templates were fabricated and fitted, and guided access was conducted with low-speed drilling, monitored with intraoperative radiographs. Canals were negotiated with K-files, and prepared with Wave One Gold system, using 2.5% NaOCl as irrigant. In all cases, virtually planned guided coronal and root canal access allied to the 3D printed templates allowed canal location through obliterated pulp spaces with a conservative access approach and without accidents. The cases demonstrated that static-guided endodontics is a safe accurate treatment approach to access calcified canals, reducing working time, minimizing removal of tooth structure, and decreasing the risk of iatrogenic damage.

Keywords: Calcified root canals, digital templates, guided endodontics, static-guided endodontics

HIGHLIGHTS

- Eleven cases of calcified root canals were successfully treated using static-guided endodontics.
- The sample encompassed four tooth types including a premolar with two canals, effectively managed using two templates.
- A high-resolution CBCT and an intraoral scan were used for virtual cavity planning.
- Templates were fabricated and fitted, and guided access was conducted with low-speed drilling.
- In all cases, static-guided coronal access allowed canal location through obliterated pulp spaces.
- A conservative access approach without accidents and with a reduced working time, was obtained in all cases.

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INTRODUCTION

A number of factors contribute to the development of pulp calcifications, including dental trauma, physiological tooth aging, or reactionary dentine apposition (1, 2). Canal obliteration is a typical late consequence of dental trauma, occurring in 9 to 40% of cases following luxation injuries (3, 4). Besides, dentine apposition within the root canal system has been observed due to stimuli such as cervical pulpotomy, restorative therapy, or prolonged orthodontic treatment (1, 2, 5). Typically asymptomatic, the calcification process is often incidentally detected during radiographic examination or may manifest as a yellowish discolouration of the affected tooth. However, over time, calcified teeth may also develop apical periodontitis, necessitating root canal treatment (6).

Pulp space obliteration poses a substantial risk for endodontic failure, because of difficulties in canal locating, penetrating, and negotiating (7). Traditionally, these cases are treated based on the clinician's knowledge of tooth anatomy, magnification, and the professional's experience. However, this approach is not predictable and iatrogenic errors such as excessive wear, deviations from the original root canal path, and root perforations are common, even among specialists (1).

To mitigate procedural errors and avoid unnecessary surgeries or even dental extractions, novel approaches such as guided endodontics have been developed to treat calcified canals, integrating 3-D technologies such as cone-beam computed tomography (CBCT), intraoral scanners, corresponding software, and 3D printers (8, 9). The traditional workflow for static-guided endodontics is based on the principle of template-guided implant surgery (10, 11). The steps include CBCT, and intraoral scanning, followed by the fabrication of a template to guide the drill to the orifice of the root canal. Once the canal is negotiated, conventional treatment can be performed. Several studies have demonstrated the accuracy (8, 12, 13) as well as the limitations (14, 15) of this technique.

The report describes a series of 11 cases of calcified root canals successfully treated using static-guided endodontics. The cases were treated by the same endodontist and encompassed four tooth types including a premolar with two canals, effectively managed using two templates.

CASE SERIES

Consent for treatment was obtained from all patients included in this case series. The eleven cases described here were treated by the same endodontist in his private practice. Guided endodontic treatment was decided based on evidence of calcified root canals with the diagnosis of endodontic pathosis based on clinical, radiographic, and CBCT findings (Table 1).

After diagnosing the need for root canal treatment, a high-resolution CBCT scan (Planmeca ProMax 3D, Helsinki, Finland) with medium (for hemiarch) or large (for total arch) field of view (FOV) was obtained (Table 2). These FOV sizes are necessary to better match the scan and the further template support, providing the necessary stabilization during canal access. An intraoral scan generated an STL file to map the mouth's surface anatomy. Using the software as listed in Table 1, the CBCT and intraoral scan were superimposed for virtual cavity planning. In the aligned 3D data set, the true-to-scale virtual image of the drill used for guided access preparation was placed so that the tip reached the visible part of the calcified root canal. Burs with their corresponding sleeves were chosen based on tooth size (Table 1). The virtual sleeve was inserted accurately to not cause drilling deviation during the procedure, with the software adjusting the distance between the template and the tooth. The templates were fabricated with PriZma 3D Bio Guide resin (BF Tecnologia 3D, Tatuí, Brazil) using the Ackuretta Freeshape 120 printer (Ackuretta, Taipei City, Taiwan).

Passing from the virtual planning to the clinic, the fit of the sleeves on the templates and the fit of the templates on the teeth were checked. The templates were placed on the patient's dentition, and a pencil lead was used to mark the entry point of the drill on the enamel. The templates were removed, and the enamel at the entry point was eliminated using a high-speed fine diamond bur. When the dentine was reached, the templates were fitted on the patient's teeth, dental dam isolation was installed, and guided access was conducted. Guided drilling advanced cautiously with low speed and "picking motions", with the bur trajectory monitored with intraoperative radiographs. External irrigation during drilling was performed with distilled water using a syringe and 25-G needle. The bur was cleaned with gauze moistened with distilled water repeatedly during the drilling.

When ledge creation was detected, they were bypassed with hand-stainless steel K-files #08 or #10 (Dentsply Maillefer, Ballaigues, Switzerland). Once the planned working length was reached, the root canals were negotiated with a K-file #08 or #10 (Dentsply Maillefer), and the working length was confirmed radiographically. Subsequently, proper root canal shaping was performed with Wave One Gold system (Dentsply Maillefer) following the manufacturer's instructions. During preparation, the canals were copiously irrigated with 2.5% NaOCl using open-ended flat NaviTip 30-G needles (Ultradent, South Jordan, UT). The conservative access aspect could be obtained in all cases. Data corresponding to each case, including diagnosis, design software, type of drill, and follow-up, are shown in Table 1.

Case 1

A 43-year-old female presented with a chief complaint of discomfort in tooth 23 when biting. During the anamnesis, she disclosed a history of undergoing seven years of orthodontic treatment, which successfully aligned that canine previously retained. Intraoral examination revealed the presence of a sinus tract on the vestibular aspect of the tooth apex, accompanied by reported tenderness upon vertical percussion and palpation in the affected area. The radiograph indicated a discreet radiolucency in the tooth's periapical region. Subsequent CBCT with medium FOV confirmed the presence of a periapical lesion at the apex of the affected tooth (6 mm×4 mm in size). The pulpal and apical diagnoses were necrosis and chronic periapical abscess. Notably, calcification was observed in the crown and middle third of the root, with a discrete canal lumen visualized in the middle and apical thirds. The calcified

TABLE 1. Data corresponding to each case

Case	Gender	Age	Tooth	PST	Percussion	Palpation	Periapical lesion (mm)*	Pulpal diagnosis	Apical diagnosis	Calcification degree by root third	Design software	Drill type	Drill: diameter/ length (mm)	Follow-up
1	Female	43	23	-	+	+	6×4	PN	CPA	Crown and middle	3Shape I.S.	Steco	1/21	1y, 6m
2	Female	74	32	-	-	-	2×1	PN	AAP	Crown	BlueSky Plan	Kinetical	0.90/21	1y
3	Female	74	31	-	-	-	2×2	PN	AAP	Crown	BlueSky Plan	Kinetical	0.90/21	1y
4	Female	74	42	-	-	-	No lesion	PN	NAT	Crown	BlueSky Plan	Kinetical	0.90/21	1y
5	Female	74	43	-	-	-	No lesion	PN	NAT	Crown	BlueSky Plan	Kinetical	0.90/21	1y
6	Female	38	21	-	+	-	4×4	PN	SAP	Crown and middle	3Shape I.S.	Steco	1/21	1y,6m
7	Female	43	21	-	+	-	1×1	PN	SAP	Crown and middle	BlueSky Plan	Kinetical	0.90/21	1y
8	Female	45	21	-	+	-	3×2	PN	SAP	Crown	3Shape I.S.	Thomas	0.90/21	1y,3m
9	Male	18	31	-	+	+	17×12	PN	SAP	Crown and middle	BlueSky Plan	Kinetical	0.90/21	1y,2m**
10	Female	65	22	-	+	-	2×2	PN	SAP	Crown	BlueSky Plan	Kinetical	0.90/21	1y, 3m
11	Male	72	14	-	+	-	2×2***	PN	SAP	Crown	3Shape I.S.	Thomas	0.90/21	1y,2m**

*: Periapical lesion measured in the CBCT, **: Contacted by telephone call, ***: Periapical lesion in buccal root. PST: Pulp sensitivity test (thermal), PN: Pulp necrosis, CPA: Chronic periapical abscess, AAP: Asymptomatic apical periodontitis, NAT: Normal apical tissues; SAP: Symptomatic apical periodontitis. Steco Drill (Steco, Hamburg, Germany); Thomas Drill, (FFDM-Tivoly, Bourges, France); Kinetical Drill (Kinetical, Buenos Aires, Argentina)

canal was successfully managed with static-guided endodontic treatment (described above) and the apical periodontitis lesion was completely healed at an 18-month follow-up (Fig. 1).

Cases 2, 3, 4, and 5

A 74-year-old female patient was referred for endodontic treatment on four mandibular teeth (31, 32, 42, and 43), deemed necessary for the subsequent prosthetic rehabilitation, requiring intraradicular retainers in all these teeth as referred to by their general dentist. Diagnosis confirmed pulp necrosis in all four teeth. Preoperative radiographs revealed atresic root canals with calcified pulp chambers in all cases. Intraoral examination confirmed the misalignment of the teeth and revealed the presence of a metal-ceramic crown on tooth 32. CBCT with large FOV revealed periapical lesions on teeth 31 (2 mm×2 mm in size) and 32 (2 mm×1 mm in size). The periapical diagnosis was asymptomatic apical periodontitis for teeth 31 and 32, and normal apical tissues for teeth 42 and 43. Three templates were produced to guide the canal access, one with two sleeves for teeth 42 and 43 and two separate templates for teeth 31 and 32. Treatment was scheduled across two sessions: the first for teeth 42 and 43, and the second for teeth 31 and 32. A one-year follow-up showed the health of the periradicular tissues, without reports of signs or symptoms of inflammation during this period (Fig. 2).

Case 6

A 38-year-old female patient presented with pain in tooth 21, making biting difficult. During the patient's anamnesis, she disclosed a recent course of antibiotics (amoxicillin 500 mg) taken two weeks prior for seven days due to pain, administered by her dentist, who attempted unsuccessfully endodontic access. Intraoral examination revealed pain upon vertical percussion, with a negative pulp sensitivity test. Notably, crown sealing material was observed on the palatal aspect of the tooth. Radiographic evaluation showed no evidence of the canal lumen and a periapical lesion, further confirmed by CBCT (4 mm×4 mm in size). Additionally, the CBCT with medium FOV revealed obliteration in the coronal and middle thirds of the root canal space. The tooth was diagnosed with pulp necrosis and symptomatic apical periodontitis. After the static-guided endodontic approach and treatment (previously described), the apical periodontitis lesion was completely healed at an 18-month follow-up (Fig. 3).

Case 7

A 43-year-old female patient was referred in pain following a failed attempt of endodontic treatment on tooth 21. During intraoral examination, the patient reported pain upon vertical percussion, and the pulp sensitivity test yielded negative results. The radiographic image indicated the absence of a root canal lumen, with the presence of radiopaque material consistent with coronal temporary sealing. The image revealed a coronal access deviation, indicating that the previous attempt intervention was interrupted because the root canal was not located. A CBCT with large FOV revealed calcification in the coronal and middle thirds of the root canal space and a periapical lesion (1 mm×1 mm in size). The diagnosis was pulp necrosis, with symptomatic apical periodontitis associated, and the static-guided endodontic approach and treatment were

TABLE 2. Cone-beam computed tomography parameters

Case	Parameters
1	Ø10.0×10.0 cm (668×668×668) 150 µm 90kV 12.5 mA 15.024 s 1783 mGy·cm^2
2-5	Ø10.0×6.0 cm (668×668×401) 150 µm 90 kV 14.0 mA 14.975 s 1220 mGy·cm^2
6	Ø4.0×5.0 cm (534×534×668) 75 µm 90 kV 10.0 mA 15.018 s 540 mGy·cm^2
7	Ø10.0×10.0 cm (668×668×668) 150 µm 90 kV 14.0 mA 15.006 s 1997 mGy·cm^2
8	Ø8.0×8.0 cm (534×534×534) 150 µm 90 kV 12.5 mA 15.022 s 1783 mGy·cm^2
9	Ø8.0×5.0 cm (534×534×334) 150 µm 90kV 14 mA 14.983 s 1303 mGy·cm^2
10	Ø10.0×10.0 cm (668×668×668) 150 µm 90 kV 14.0 mA 14.958 s 2033 mGy·cm^2
11	Ø8.0×8.0 cm (534×534×534) 150 µm 90 kV 12.5 mA 14.956 s 1783 mGy·cm^2

The size of the image acquisition area is represented by Ø. The FOV in millimeters is shown in parentheses.

initiated (previously described). A one-year clinical and radiographic follow-up showed a favourable outcome (Fig. 4).

Case 8

A 45-year-old female patient sought treatment because of the discolouration of tooth 21. During the anamnesis, she recalled a traumatic injury in that tooth during childhood, which did not result in a crown fracture. Radiographic examination revealed a periapical lesion (3 mm×2 mm in size) on tooth 21, confirmed by CBCT with large FOV. Additionally, calcification of the coronal third of the root canal was evident. Intraoral examination revealed pain upon vertical percussion, with a negative pulp sensitivity test. Tooth discoloration was notably pronounced. The diagnosis rendered was pulp necrosis and symptomatic apical periodontitis. Coronal access was performed with a static endodontic-guided approach, followed by conventional root canal treatment as previously described. Follow-up at one year and three months showed the health of the periradicular tissues (Fig. 5).

Case 9

An 18-year-old male patient with autistic spectrum disorder presented for consultation due to color changes and intense pain in tooth 31. During the anamnesis, he recounted experiencing dental trauma without crown fracture at the age of nine. Periapical radiograph revealed a large radiolucency in the apical region of tooth 31, extending to neighboring teeth. Subsequent CBCT with large FOV confirmed the presence of a sizable periapical lesion involving the tooth apex (17 mm×12 mm in size). Furthermore, calcification of the coronal and middle thirds of the root canal was evident. A very discrete image of the canal lumen was perceived in the apical region on the CBCT. At intraoral examination, the patient reported pain upon vertical percussion, with a negative pulp sensitiv-

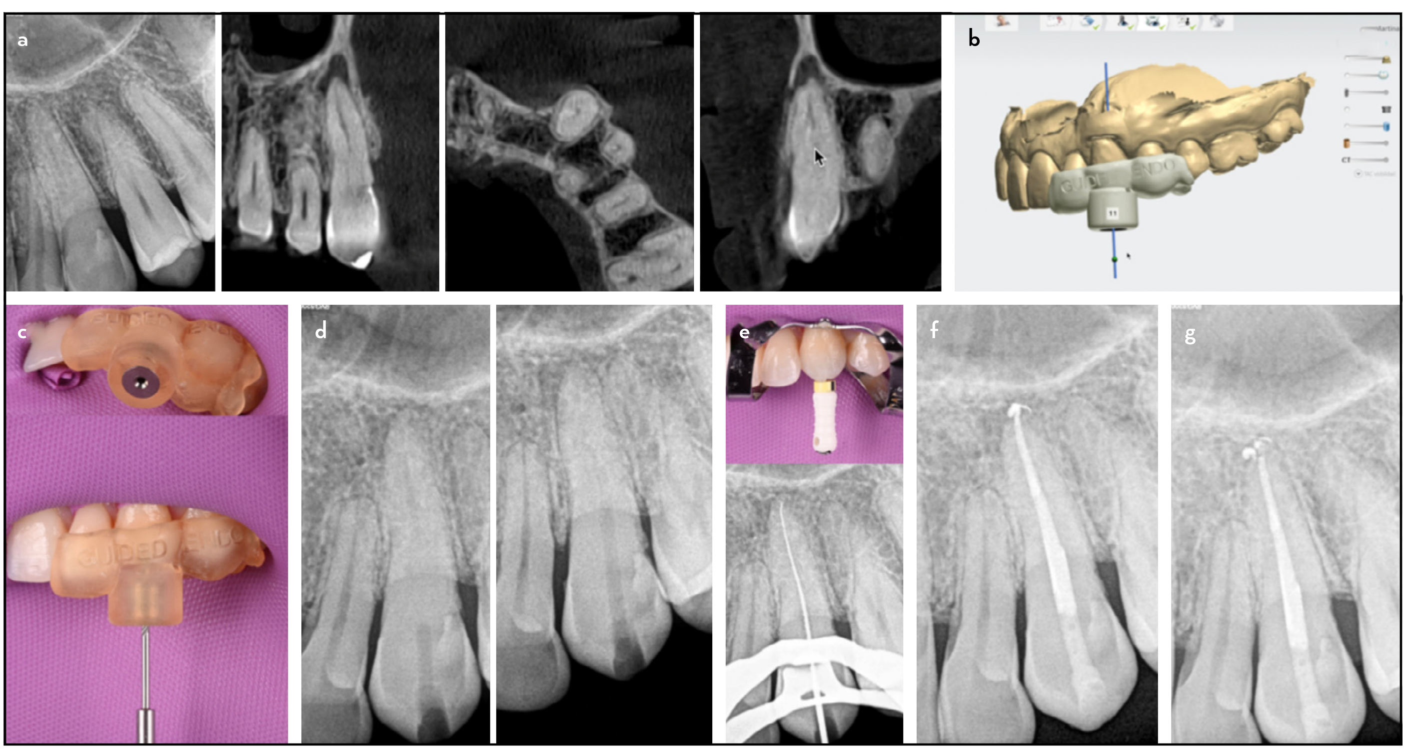

Figure 1. Case 1. (a) Preoperative radiograph and CBCT scan showing the degree of calcification in the root canal and periapical lesion. (b) Endodontic guide design. (c) Isolation, fit of the template, and guided access. (d) Intraoperative radiographs monitoring the trajectory of the bur. (e) Access to the working length with a K-file #15 file. (f) Postoperative radiograph. (g) Follow-up radiograph at one year and six months

CBCT: Cone beam computed tomography

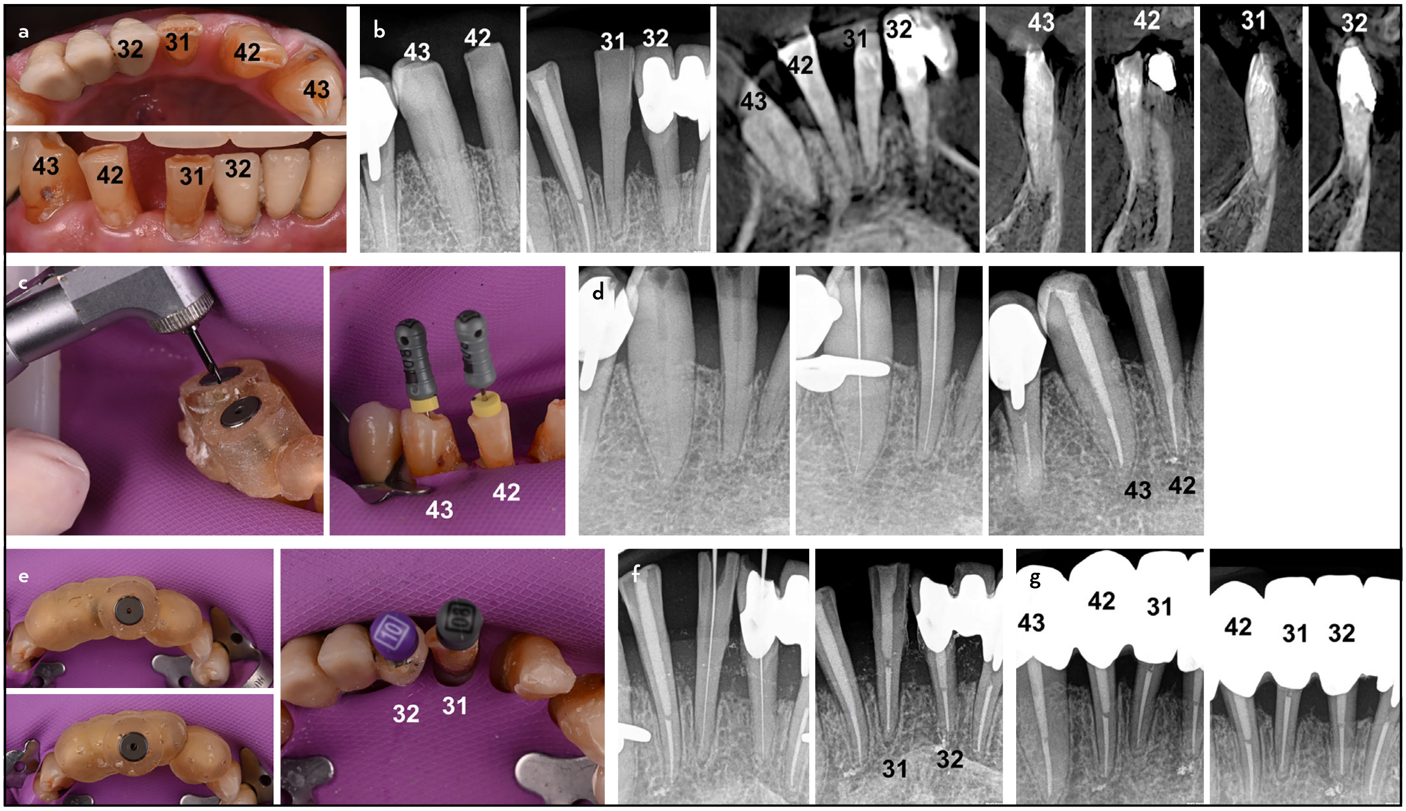

Figure 2. Cases 2, 3, 4 and 5. (a) Clinical photographs of target teeth (31, 32, 42, and 43). (b) Preoperative radiographs and CBCT scans. (c) Guided access using a single template with two sleeves for teeth 42 and 43, respectively. (d) Radiograph monitoring the trajectory of the bur, working length, and post-operative radiographs of teeth 42 and 43. (e) Separate templates for guided access of teeth 31 and 32, after opening the prosthetic crown with a transmetal bur. (f) Radiographic sequence of treatment for teeth 31 and 32, including immediate postoperative status. (g) One-year follow-up

CBCT: Cone beam computed tomography

ity test for tooth 31. However, pulp sensitivity tests yielded positive results for the remaining lower incisors. The diagnosis for tooth 31 was pulp necrosis and symptomatic apical periodontitis. Not only coronal but also radicular access were performed using the static endodontic-guided approach until the apical third was reached when the canal lumen could be explored, and the endodontic treatment was completed as previously described. The patient did not attend the recall appointments at 6 months and 1 year, because of problems related to his psychiatric condition but the absence of symptoms was reported during telephone contact passed 1 year and two months after treatment conclusion (Fig. 6).

Case 10

A 65-year-old female patient had a chief complaint of pain in tooth 22 when biting. Intraoral examination revealed multiple resin restorations on the tooth and pain upon vertical percussion, with a negative pulp sensitivity test. The periapical radiographic image showed calcification of the coronal portion of the root canal and multiple radiopaque restorations. CBCT with large FOV confirmed the calcification, indicating the root canal beginning after the cervical third, and a periapical lesion at the root apex of the affected tooth (2 mm×2 mm in size). The diagnosis of tooth 22 was pulp necrosis and symptomatic apical periodontitis. Successful treatment was achieved with static-guided endodontic treatment, and the apical periodontitis lesion completely healed at one year and three months follow-up (Fig. 7).

Case 11

A 72-year-old male patient presented with pain in the maxillary right premolar region and was seeking treatment. Intraoral examination revealed caries in tooth 14 and reported pain upon vertical percussion. The periapical radiograph depicted coronal calcification of the root canals, corroborated by CBCT with medium FOV, which also revealed pulp canal obliteration in the coronal portion of both roots and a periapical lesion associated with the buccal root (2 mm×2 mm in size). The pulp and apical diagnoses were necrosis and symptomatic apical periodontitis. After caries removal, successful coronal access was achieved with the static-guided endodontic approach, which allowed the patency establishment. After that, the root canal treatment of both buccal and palatal canals was performed. The patient did not attend the 6-month and 1-year recall appointments because the patient was undergoing cancer treatment but reported the absence of signs or symptoms during telephone contact (Fig. 8).

DISCUSSION

Guided endodontics is constantly evolving, and it has been applied in several treatment protocols, including auto-transplantation of teeth, apical microsurgery, and management of root canal obliterations (9, 16, 17). The present case series included 11 teeth in which calcified canals were successfully accessed using static-guided endodontics. In some cases, the calcification was so pronounced that no evidence of canal lumen could be discerned on periapical radiographs. However,

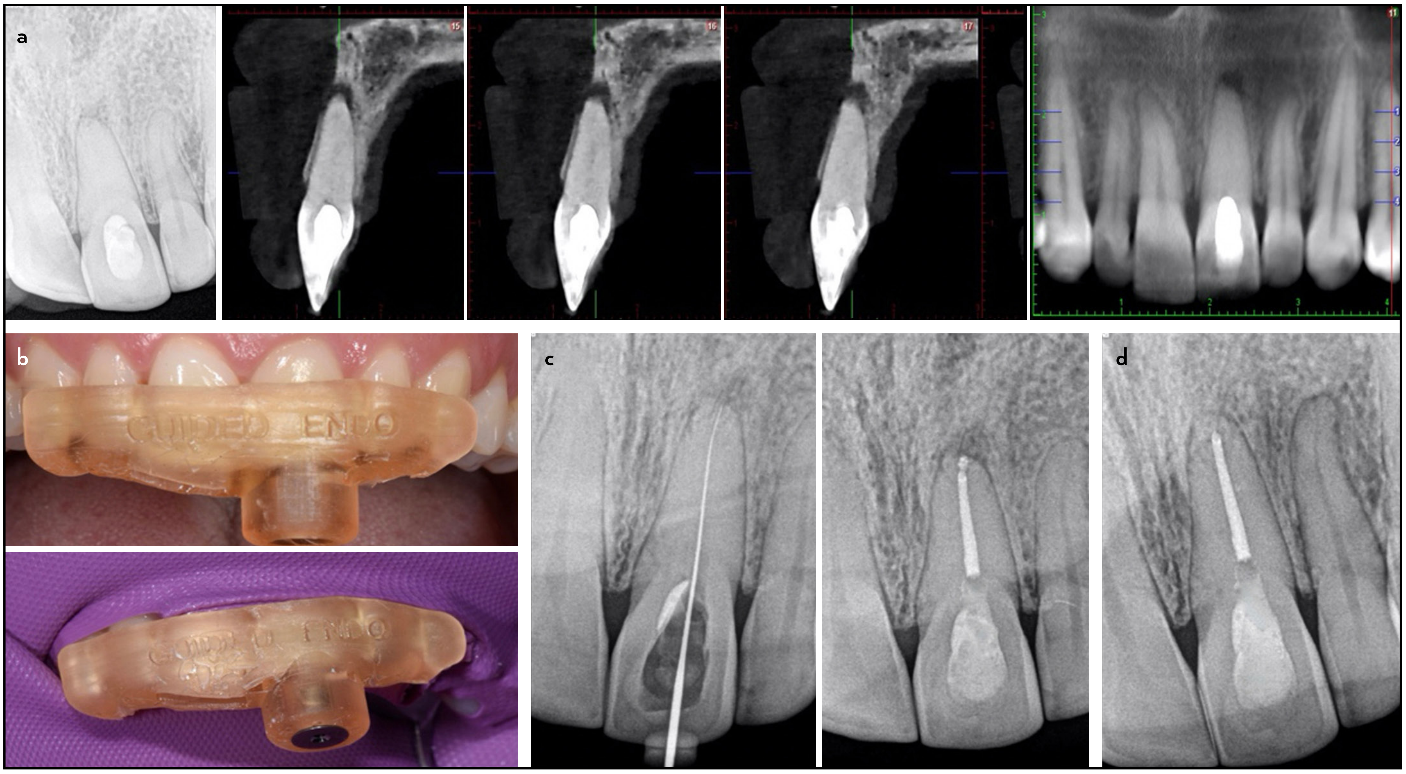

Figure 3. Case 6. (a) Preoperative radiograph and CBCT scan showing the degree of calcification in the root canal and the presence of a periapical lesion. (b) Fit of the template, isolation, and guided access. (c) Radiograph confirming root canal access and immediate postoperative status. (d) Follow-up radiograph at one year and six months

CBCT: Cone beam computed tomography

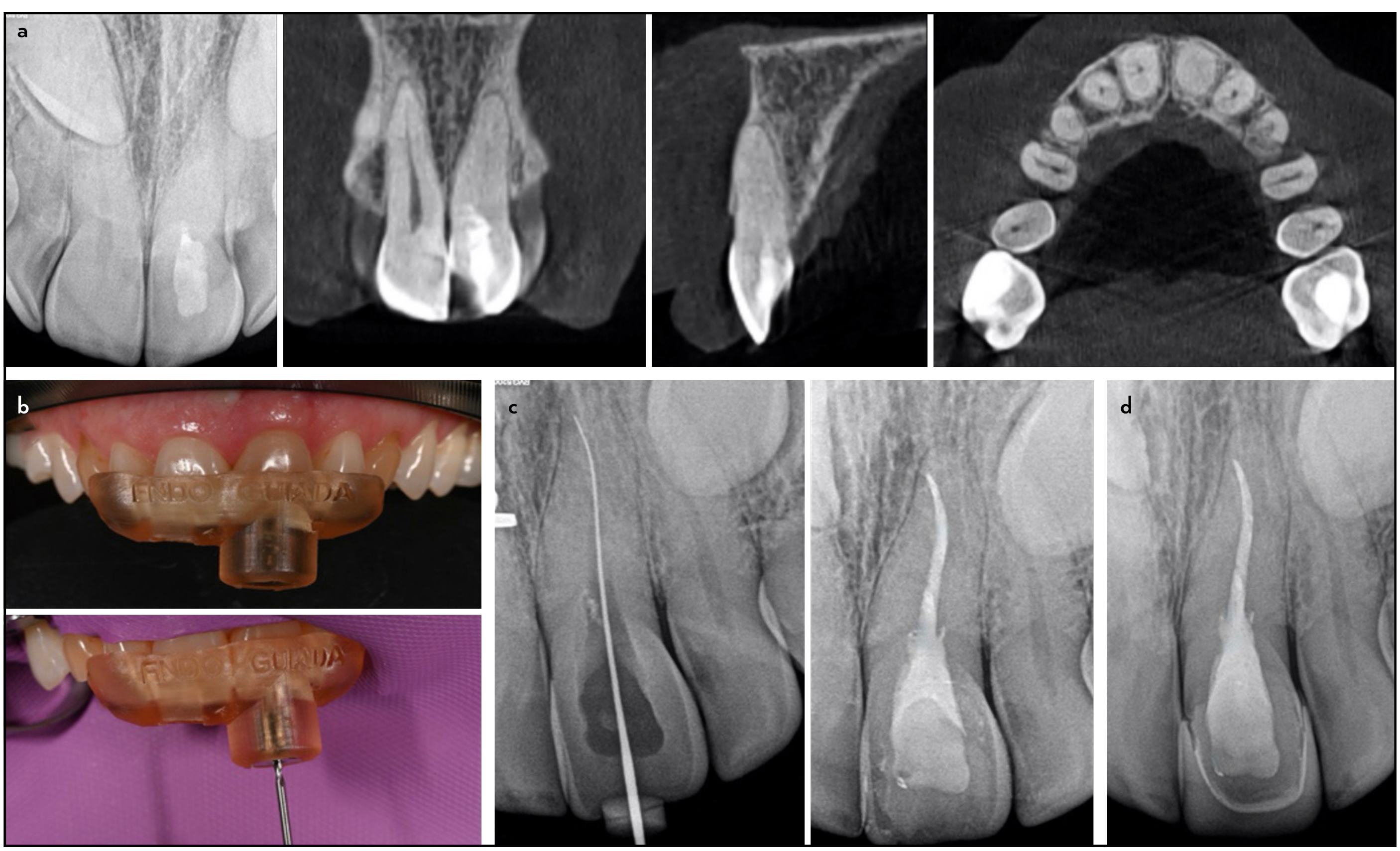

Figure 4. Case 7. (a) Preoperative radiograph and CBCT scan. (b) Proper fit of the template and drill used for guided access preparation. (c) Radiographs confirming root canal access and immediate postoperative status. (d) One-year follow-up radiograph

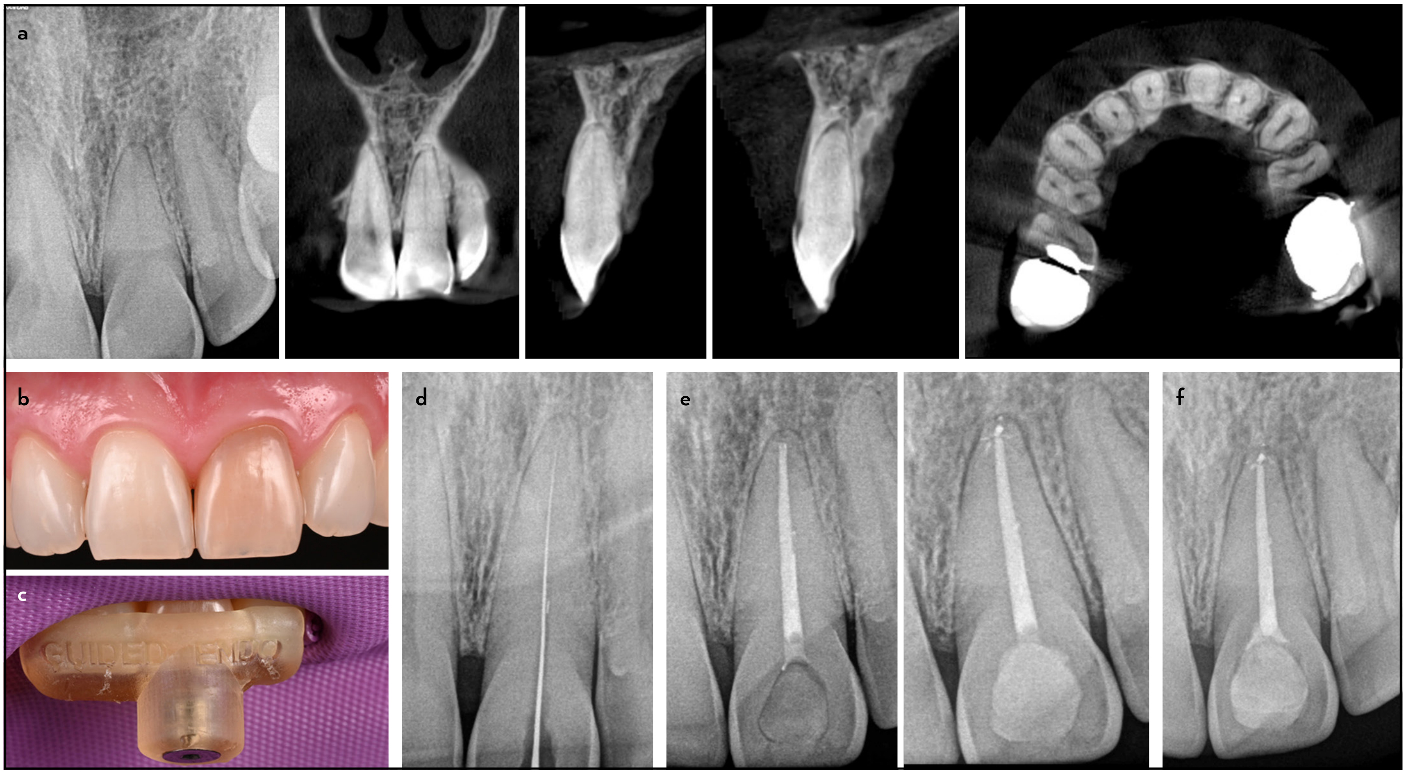

Figure 5. Case 8. (a) Pre-operative radiograph and CBCT scan showing the degree of root canal obliteration and the periapical lesion. (b) Tooth crown discoloration. (c) Template fitting and placement. (d) Radiograph confirming root canal access. (e) Immediate postoperative status and follow-up radiograph at one week showing definitive restoration. (f) Follow-up at one year and three months

CBCT: Cone beam computed tomography

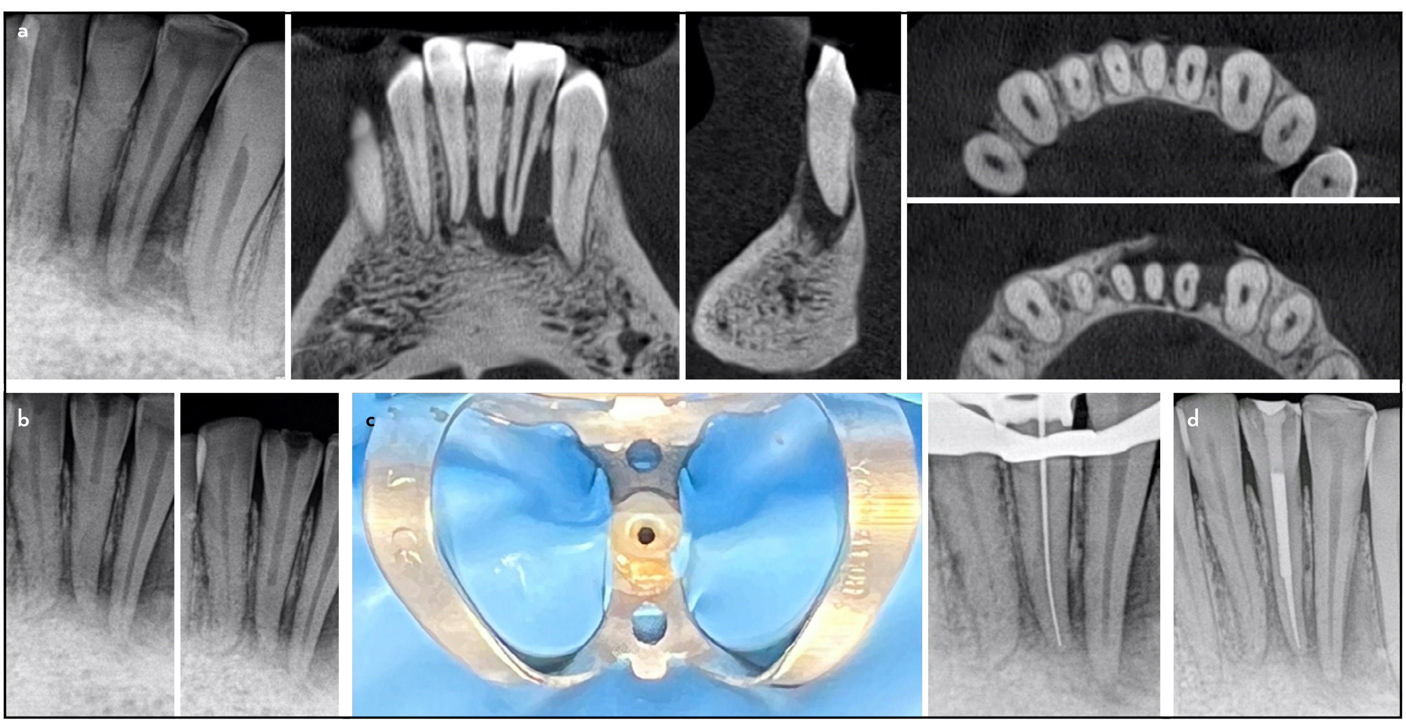

Figure 6. Case 9. (a) Pre-operative radiograph and CBCT scan showing the degree of root canal obliteration and periapical lesion. (b) Intraoperative radiographs monitoring drilling depth and the trajectory of the bur. (c) Photograph showing the minimally invasive approach, and radiograph confirming root canal access. (d) Postoperative radiograph. A clinical view with the guide placement is not available in this case

in all cases, a conservative access approach was achieved, without any perforation or instrument fracture, underscoring the precision of the procedures. This methodology aligns with the principles of minimally invasive endodontics, promoting the preservation of tooth structure and minimizing the risk of iatrogenic complications.

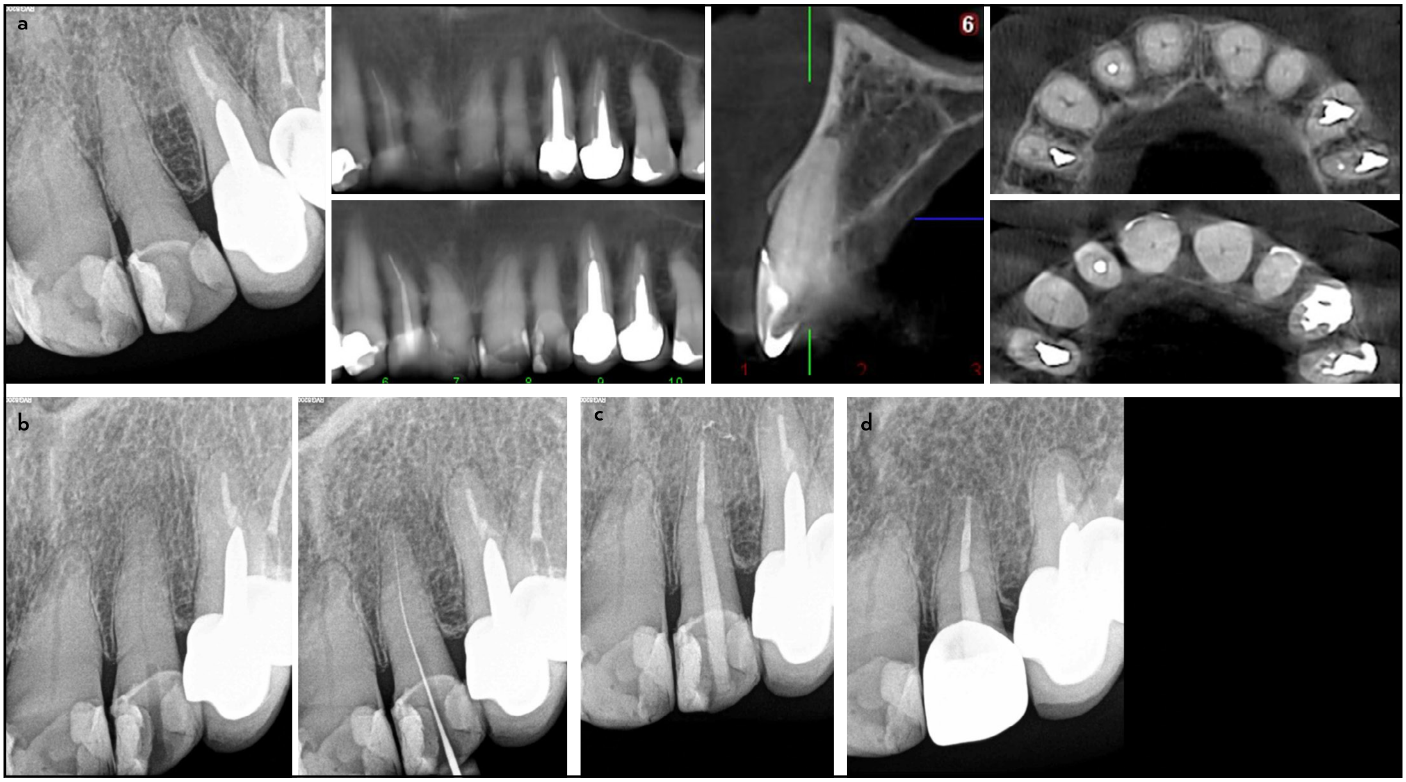

Figure 7. Case 10. (a) Preoperative radiograph and CBCT scan. (b) Intraoperative radiograph monitoring the trajectory of the bur and radiograph confirming root canal access. (c) Immediate postoperative radiograph. (d) One-year follow-up

CBCT: Cone beam computed tomography

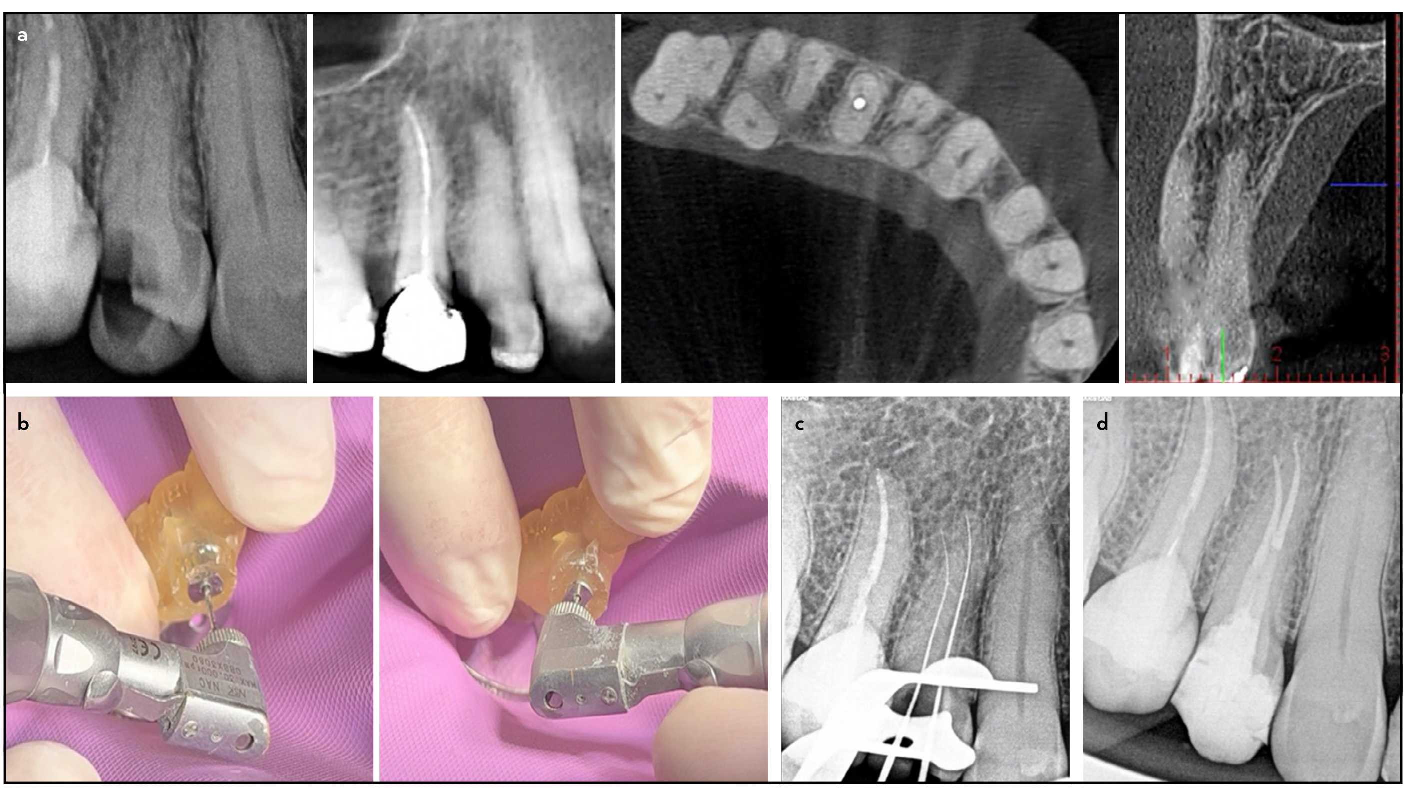

Figure 8. Case 11. (a) Preoperative radiograph and CBCT scan. (b) Two separate guides were used for the buccal and palatal roots, respectively. (c) Radiograph confirming root canal access and patency. (d) Postoperative radiograph

Locating calcified root canals via freehand coronal access often leads to iatrogenic procedural errors such as deviations, perforations, and weakening of the remaining tooth structure (7). Conversely, static-guided endodontics offers a more predictable location and, consequently, negotiation of calcified root canals with significantly less loss of healthy tissue (12, 18, 19). This approach also reduces the working time for both the professional and the patient, a notable benefit, particularly for patients with special conditions, as observed in case no. 9, in which the patient was autistic (8). A recent study comparing the accuracy of access cavity preparations with and without guides by operators with different levels of clinical experience showed that the guides achieved accurate conservative access cavities regardless of the operator's skills (20).

According to a previous study (21), longer pulp space obliterations seem to be more frequent in maxillary teeth in comparison with mandibular, which was also observed in the present reports. The same study also found that mandibular teeth showed a significantly higher number of optimal precision scores when performing static-guided coronal access.

A recent study (22) compared the static guides with a dynamic navigation system (Denacam) and with the freehand technique for access cavity preparation regarding accuracy. The methods were applied in calcified root canals or canals presenting pulp stones. Static navigation demonstrated the highest accuracy in cavity preparation, while the freehand technique exhibited greater deviations in angle, entry, and bur tip placement. However, it is important to emphasize that dynamic navigation overcomes the limitations of static templates regarding challenges like dental dam placement, debris rinsing, and limited mouth opening.

Considerations must be made regarding the limitations of static-guided endodontics to ensure appropriate case selection and planning. This technique is limited when mouth opening is restricted, a direct straight path through the obliterated part of the root canal is unfeasible, or when patients use aligners or orthodontic devices that may alter tooth position between planning and treatment delivery (23). Furthermore, the success of guided endodontics depends on the quality of intraoral and CBCT scans, as well as the precision of template design, which must fit tightly on the patient's dentition. Additionally, when selecting the drill, factors such as root canal length, diameter, and wall thickness must be considered. Importantly, if the root canal is not visualized on the CBCT images, this technique should not be utilized. Apical surgery must be considered not only in such cases but also when straight-line access through the obliterated part of the root canal is unattainable, particularly in curved root canals (14, 15).

In this context, several clinical recommendations can be highlighted to reduce the risks associated with endodontic procedures in calcified root canals. These include the use of advanced technologies, starting with the CBCT, a valuable tool not only for studying the anatomical aspects of the case but also for guiding the treatment process (24, 25). Additionally, during interventions, the use of magnification and high-power illumination, such as dental loupes or microscopes, significantly enhances visibility, facilitating the accurate location and negotiation of canals (24, 26). Combining magnification with ultrasonic tips for exploring coronal access, along with prior anatomical knowledge and CBCT data, often increases the likelihood of success. However, despite these strategies, deviations, and perforations remain common in calcified canals due to the inherent risks of freehand techniques (6). To mitigate these risks, static-guided endodontics should be incorporated, particularly in more complex cases.

Guided coronal access is emerging as more accurate and aligned with minimally invasive endodontics by providing greater accuracy and reduced tooth substance loss compared to freehand cavity preparation. This trend is increasing due to the growing incidence of tooth obliterations attributed to aging, the expanding use of regenerative endodontic procedures, and interventions involving fiber post insertions or removals. Consequently, it underscores the necessity for proficient training in guided endodontics to ensure optimal outcomes.

CONCLUSION

Static-guided endodontics proved to be a safe and accurate technique in the clinical cases of calcified root canal treatments described here. This approach may be a valuable tool for negotiating obliterated root canals, thereby reducing working time, the risk of excessive removal of tooth structure, and iatrogenic damage to the root.

Disclosures

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Informed consent: Written informed consent was obtained from the patient for the publication of the case report and the accompanying images.

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