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Classification proposal of obliterated canals based on the position of the target point and the caliber of the root canal

Gustavo Adolfo Castillo Barrios[1], **Patricia Rodríguez Sánchez**[1], **Anuar Elian Barona Triviño**[1], **Carlos Humberto Martínez Cajas**[2,*]

[1]Department of Endodontics, Universidad del Valle, Cali, Colombia
[2]Clinical Specialization Programs in Dentistry, Institución Universitaria Colegios de Colombia (UNICOC), Cali, Colombia

ABSTRACT

Objectives: This study aimed to propose a classification system for calcified root canals based on the location of the target point or canal starting point and root canal lumen caliber to facilitate the evaluation of dynamically guided techniques in endodontic treatment.

Methods: A retrospective analysis of eight cases with calcified root canals was conducted. Periapical radiographs and cone-beam computed tomography were used to classify cases based on root location and degree of obliteration. Clinical and radiographic outcomes were evaluated.

Results: Seven classification types were identified, ranging from partial obliteration to total obliteration. The location of the root canal lumen varies from the pulp chamber to the apical third of the root. Guided endodontics with dynamic navigation has been demonstrated to be an effective treatment modality in cases of advanced obliteration, thereby substantiating its efficacy in complex scenarios.

Conclusions: The proposed classification system provides a framework to understand the complexity of calcified root canals. Guided endodontics with dynamically guided techniques can be valuable in managing these challenging cases, particularly when the root canal lumen is in the apical third. Further studies are needed to validate the classification system and evaluate the long-term outcomes of the different treatment approaches.

Keywords: Cone-beam computed tomography; Dental pulp; Dental pulp calcification; Dental radiography; Tooth injuries

INTRODUCTION

Conventional endodontic treatment involves shaping, cleaning, and disinfecting the root canal system due to inflammation or pulp necrosis [1] caused by extensive caries, dental trauma, and dental procedures such as extensive restorations and crowns. Low- or moderate-intensity dental trauma can stimulate the cells of

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***Correspondence to**
Carlos Humberto Martínez Cajas, DDS, MSc
Clinical Specialization Programs in Dentistry, Institución Universitaria Colegios de Colombia (UNICOC), Cl. 13N No. 3N-13, Santiago de Cali, Valle del Cauca 760046, Colombia
Email: cmartinezc@unicoc.edu.co

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the pulp tissue, causing calcification or obliteration of the root canal in response to this noxious stimulus [1,2]. These obliterations, caused by trauma, can occur in 40% of cases, and the need for endodontic treatment varies between 7% and 27% due to the presence of symptoms, crown discoloration, or radiographic findings with the presence of periapical pathology [3]. Other causes of pulp canal obliteration include orthodontic treatment, revascularization, and advanced age [4].

In 2000, Bastone *et al.* [5] reported that the frequency of dentoalveolar trauma was high among school and university students. Subluxation and low-intensity luxation such as extrusion and lateral luxation are the main causes of calcification in the root canal [2]. Andreasen *et al.* [1] reported a 15% rate of root canal obliteration after observing 637 injured teeth; similarly, Bastos and Côrtes [6] in 2018 reported a percentage of pulpal obliteration ranging from 3.7% to 40% in these cases. The mechanism by which pulp canal obliteration or calcific metamorphosis occurs remains unknown, and in efforts to explain it, the approach of Siddiqui and Mohamed [7] is highlighted, who propose that it may be produced by an injury to the neurovascular supply of the pulp. The presence of obliteration of the canal system can be identified through changes in tooth color or during a routine dental examination. Oginni *et al.* [4] in 2009, evaluated teeth with pulpal canal obliteration and reported that 79.71% of teeth presented a coronal discoloration (yellow or gray) and 33.3% with an apical lesion. However, endodontic treatment is not always indicated until a complete clinical evaluation of the patient's signs and symptoms is performed [8]. According to Jain *et al.* [3], endodontic therapy is indicated in 7%–27% of cases if they present with symptoms or radiographic evidence of apical periodontitis.

Conventional canal treatments are commonly accompanied by periapical radiographs because of their low radiation doses and low costs. However, endodontic treatments in the presence of obliterations, which are considered to have a higher degree of difficulty, require the use of high-resolution tomography because of the greater amount of information they provide about root anatomy and morphology. Currently, the European Society of Endodontics supports the use of tomographic images for the assessment and resolution of complex cases, in addition to being necessary for any type of dynamic or static navigation [9]. Due to this reduction in the canal lumen, the execution of endodontic treatments becomes more complex because of the difficulty of locating and negotiating the root canals correctly and conservatively. Connert *et al.* [10] report high percentages of deviation (success in only 41.7% of cases) with the freehand technique, even with the aid of tomography and magnification; currently, computer-assisted navigation techniques (static and/or dynamic navigation) are much more precise for performing these procedures [11,12]. Even with the use of these navigation systems, the location of the root canals is complex and varies depending on the degree of pulp obliteration and the location at the beginning of the root canal lumen (target point) [13]. These anatomical characteristics are normally observed with the help of periapical radiography, especially using high-resolution cone-beam computed tomography (CBCT), which is indicated in cases of greater complexity [14].

Radiographically, the obliteration of the pulp canals can be classified into two types: partial obliteration, in which the pulp chamber is not observed and the canal is considerably calcified; and total obliteration, in which the pulp chamber and root canal are practically imperceptible radiographically [7,8].

MAIN SUBJECTS

Classification of calcified canals

High-quality periapical radiographs and a high-resolution CBCT (ranging from 75 to 100 μm) are recommended to assess the presence of the root canal lumen and its subsequent classification. This classification comprises seven categories as follows (Figure 1).

1. Type Ia: Partial obliteration with predominant vertical constriction (coronal initiation)

Presence of discernible canal lumen above the cement-enamel junction (CEJ) with progressive corono-apical calcification. The root canal maintains radiographic visibility throughout its length despite marked coronal narrowing. Radiographically, the intracanal radiolucency (representing the patent canal lumen) measures >50% of the estimated normal canal width at the

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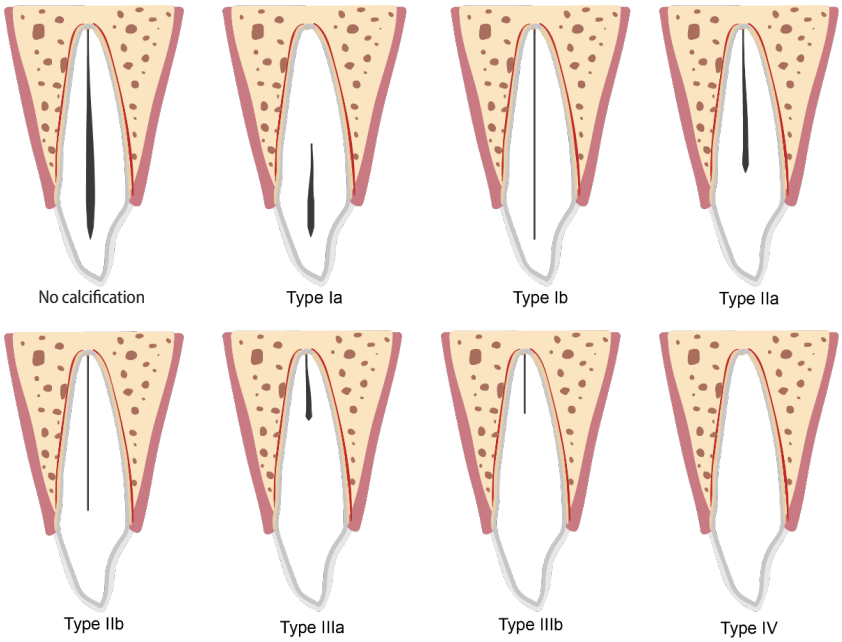


Figure 1. Classification proposal of calcified canals.

cervical third, with constriction predominantly affecting the vertical (corono-apical) dimension. The target point (canal orifice) remains clearly locatable on radiographic examination.

Distinguishing feature: minimal to absent horizontal (circumferential) constriction of the canal walls.

2. Type Ib: Advanced obliteration with vertical and horizontal constriction (coronal initiation)

Advanced calcification beginning above the CEJ, demonstrating both significant vertical (corono-apical) and horizontal (circumferential) constriction of the root canal. The visible intracanal radiolucency is reduced to ≤50% of the normal canal width, with radiodensity approaching but not identical to surrounding dentin. The canal lumen remains discernible on radiographs, though requiring careful examination. Apical patency of the canal is maintained.

Distinguishing features: pronounced bilateral constriction patterns and substantially reduced lumen visibility compared to Type Ia, while lumen identification remains feasible.

3. Type IIa: Partial obliteration with minimal horizontal constriction (cervical-middle initiation)

Partial calcification beginning between the CEJ and the middle third of the root. The pulp chamber remains visible, though reduced in volume. The intracanal radiolucency exceeds 50% of the estimated normal canal width at the level of obliteration onset, indicating predominant vertical constriction with minimal horizontal (circumferential) involvement. The radiodensity differential between the calcified zone and surrounding dentin remains evident, allowing clear delineation of the obliterated region. Apical to the calcified zone, canal patency is evident.

Distinguishing feature: preserved circumferential canal wall outline and relatively open apical anatomy.

4. Type IIb: Advanced obliteration with concurrent vertical and horizontal constriction (cervical-middle initiation)

Advanced calcification originating between the CEJ and the middle third of the root, characterized by severe bilateral constriction (both corono-apical and circumferential). The visible canal lumen is reduced to ≤50% of the normal estimated diameter. Radiographic visualization reveals a marked reduction in radiodensity differ-

ential (approaching dentin equivalence), making canal identification challenging. The transition zone between obliterated and patent canal is distinct but narrow.

Distinguishing feature: pronounced 360º circumferential constriction combined with significant vertical narrowing; increased difficulty in lumen identification without magnification or three-dimensional imaging.

5. Type IIIa: Partial obliteration with preserved apical patency (middle-third or apical initiation)

Partial calcification with onset in the middle third of the root or apical region, leaving the coronal two-thirds patent. The intracanal radiolucency in the non-obliterated zones exceeds 50% of normal canal width. Horizontal (circumferential) constriction is minimal to absent. The calcified zone is clearly distinguishable radiographically from surrounding dentin by virtue of maintained radiodensity differential. Considerable patent canal space remains accessible for negotiation both coronally and apically.

Distinguishing feature: obliteration limited to specific root thirds with well-preserved access anatomy and target point identification.

6. Type IIIb: Advanced obliteration with severe constriction (middle-third or apical initiation)

Advanced calcification beginning in the middle third or apical region, featuring pronounced vertical and horizontal constriction within the obliterated zone. The visible canal lumen is ≤50% of normal width within the calcified region. Radiodensity approaches dentin equivalence, substantially reducing the radiographic differential. While obliteration is localized, the calcified zone presents severe bilateral constriction, necessitating advanced diagnostic imaging (CBCT) or magnification for precise lumen identification. Patent canal anatomy is preserved both coronally and apically, yet access through the constricted zone is substantially compromised.

Distinguishing feature: high-grade constriction (>50% volume reduction) within a localized calcification zone, combined with radiodensity near equivalence to dentin.

7. Type IV: Total obliteration with complete radiodensity equivalence

Complete obliteration of the root canal throughout its entire length from the pulp chamber to the apical foramen. Radiographically, the entire pulp space demonstrates radiodensity equivalent to or exceeding surrounding dentin, rendering the intracanal lumen non-discernible on conventional radiography. No visible radiolucency representing patent canal space remains at any level. The distinction between the canal space and surrounding dentin is absent or imperceptible.

Distinguishing feature: absolute absence of radiographic canal visibility and uniform radiodensity throughout the canal path.

Classification proposal and case examples

1. Classification Type Ia: Partial obliteration with predominant vertical constriction (coronal initiation)

- Example 1: A 52-year-old female patient with no medical history was referred for endodontic treatment of the upper right lateral incisor without presenting any symptoms. A clinical examination was conducted, which revealed a negative sensitivity test result. Radiographic analysis revealed the presence of a radiolucent area in the apical region, indicative of a periapical osteolytic lesion. The root canal lumen was found to be obliterated, resulting in a reduced lumen within the root canal system within the pulp chamber. The diagnosis was confirmed as asymptomatic apical periodontitis. Subsequent tomographic analysis guided the decision to perform root canal treatment with magnification and freehand techniques, owing to the presence of a small periapical radiolucent area. The infiltration of anesthesia was facilitated using a 2% lidocaine solution with 1:80,000 epinephrine, and the procedure was conducted under the guidance of a microscope and a #3 round diamond bur. The canal was then prepared using a #10 hand file and irrigated with 5.25% sodium hypochlorite (NaOCl). A WaveOne Gold primary system (Dentsply Maillefer Instruments Holding Sàrl, Ballaigues, Switzerland) was then utilized. Subsequently, the canal was obturated using WaveOne Gold cone and AH Plus root canal sealer (Dentsply

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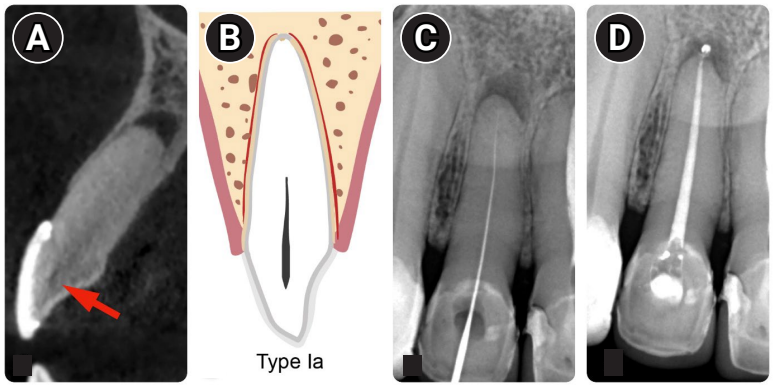


Figure 2. Characteristics of Type Ia root canal classification. (A) Tomographic image. The red arrow indicates the target point (start of the canal) without any change from its original position. It is clearly visible in the sagittal cone-beam computed tomography view. The root canal disappears at the start of the cervical third of the root. (B) Type Ia classification scheme. (C) Initial root canal negotiation with a file to determine the temporary working length. (D) Filled canal.

DeTrey GmbH) (Figure 2).

2. Classification Type Ib: Advanced obliteration with vertical and horizontal constriction (coronal initiation)

- Example 2: A 72-year-old female patient with a history of controlled hypertension was referred for intermittent symptoms and canal obliteration in the lower right central incisor. The patient reported positive vertical and horizontal percussion and a negative sensitivity test during the clinical examination. Radiographically, a radiolucent area was observed apically, compatible with a lesion of pulpal origin, and a decrease in the lumen throughout the root canal, with the beginning of the canal lumen in the pulp chamber. Apical periodontitis was defined as a diagnosis, and conventional endodontics was the ideal treatment. Due to the tomographic analysis, it was decided to perform the treatment with magnification and a 1 mm Steco bur freehand. A palatal access was made near the incisal edge to have an access path perpendicular to the long axis of the tooth. Canal patency occurred in the coronal third with little wear of the remaining tooth within a few minutes. Subsequently, the canal was instrumented with a medium WaveOne Gold file, copiously irrigated, activated with 5.25% sodium hypochlorite, and filled with a gutta-percha cone of the same system and Bio-C Sealer cement. Finally, the patient was referred for lingual resin (Figure 3).

3. Classification Type IIa: Partial obliteration with minimal horizontal constriction (cervical-middle initiation)

- Example 3: A 46-year-old female patient was referred for locating the canal and performing conventional endodontic treatment on the lower right central incisor, with a diagnosis of asymptomatic apical periodontitis. A CBCT image was obtained to establish the diagnosis and treatment plan. The results established obliteration of the pulp chamber and partial calcification of the canal, with the beginning of the canal lumen above the middle third of the root. A periapical radiolucent area compatible with a lesion was also observed. Subsequently, the DICOM files from the tomography were used to perform digital planning in the software Navident dynamic navigation system (ClaroNav Inc., Toronto, ON, Canada). A Steco bur endodontic guided bur (Steco-system-technik GmbH & Co. KG, Lemgo, Germany) was used to achieve patency. The target point of the tooth was located between the middle and cervical thirds with a pre-curved #10 file. Subsequently, the canal was instrumented using the HyFlex CM rotary NiTi files #30 (Coltene/Whaledent AG, Altstätten, Switzerland), irrigated with sodium hypochlorite, and obturated using the lateral condensation technique with AH Plus (Figure 4).

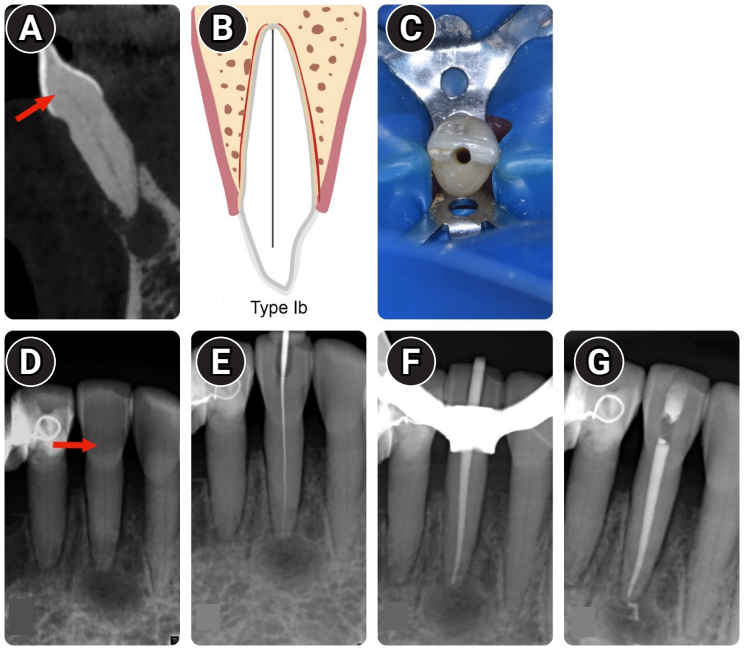


Figure 3. Characteristics of Type Ib root canal classification. (A) Tomographic image. The red arrow indicates the target point (start of the canal), which is located in its original position; however, narrowing of the canal lumen is observed along the entire root. (B) Type Ib classification scheme. (C) Access to pulp cham ber/root canal. (D) Initial radiograph. The red arrow indicates narrowing of the root canal along the entire root. (E) Initial root canal negotiation with a file to determine the temporary working length. (F) Gutta-percha master point fitting before root canal filling. (G) Filled canal.

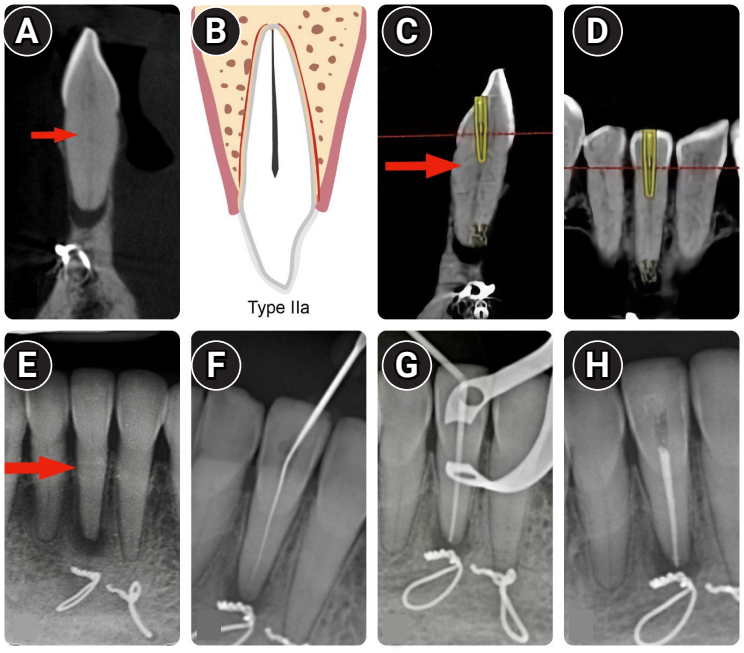


Figure 4. Characteristics of Type IIa root canal classification. (A) Tomographic image. The red arrow indicates the start of the canal lumen (target point). (B) Type IIa classification scheme. (C) Planning access to the pulp chamber/root canal in a sagittal slice. The red arrow indicates the target point for planning (start of the canal lumen). (D) Planning for pulp chamber/root canal access coronal slice. (E) Initial radiograph. The red arrow indicates the start of the root canal. (F) Initial root canal negotiation with a file to determine the temporary working length. (G) Gutta-percha master point fitting before root canal filling. (H) Filled canal.

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4. Classification Type IIb: Advanced obliteration with concurrent vertical and horizontal constriction (cervical-middle initiation)

- Example 4: A 27-year-old man presented with pain in the upper right central incisor upon percussion. With no significant medical history, clinical examination revealed a negative response to cold testing and a positive reaction to vertical percussion. Radiographic findings showed a periapical radiolucency, indicative of a periapical lesion, along with partial obliteration of the root canal and no visible canal orifice in the pulp chamber. A diagnosis of symptomatic apical periodontitis was made, and conventional endodontic treatment was planned.

Access preparation began with the removal of enamel using a #2 round diamond bur. The opening was extended towards the incisal edge to ensure a straight-line access parallel to the long axis of the tooth. A pencil mark was placed on the vestibular surface for orientation. A 1-mm Steco bur was used in a low-speed handpiece to locate the canal orifice. The canal was then cleaned and shaped with a #10 file and a WaveOne Gold primary file (size 25) and obturated with a corresponding gutta-percha cone and Bio-C Sealer. The patient was referred for restorative treatment and scheduled for a 6-month follow-up (Figure 5).

5. Classification Type IIIa: Partial obliteration with preserved apical patency (middle-third or apical initiation)

- Example 5: A 25-year-old female patient was referred by an endodontist to locate the canal and obturate the upper right central incisor. The patient had no systemic medical conditions. She had a history of orthodontic treatment 2 years ago. A clinical examination revealed a negative sensitivity test. Radiographically, a decrease in the canal lumen was observed up to the middle-third of the root. A diagnosis of pulpal necrosis was made, and guided endodontics was determined to be the ideal treatment. The initial tomography was performed after creating a small opening with a #2 round diamond bur. These DICOM files from the tomography were import-

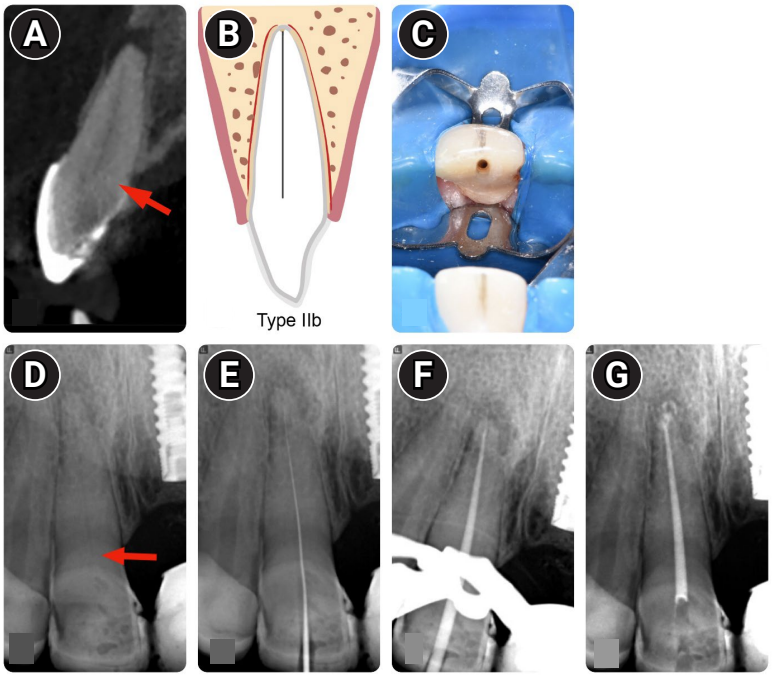


Figure 5. Characteristics of Type IIb root canal classification. (A) Tomographic image. The red arrow indicates the start of the canal lumen (target point). (B) Type IIb classification scheme. (C) Access to pulp chamber/root canal. (D) Initial radiograph. The red arrow indicates the start of the root canal. (E) Initial root canal negotiation with a file to determine the temporary working length. (F) Gutta-percha master point fitting before root canal filling. (G) Filled canal.

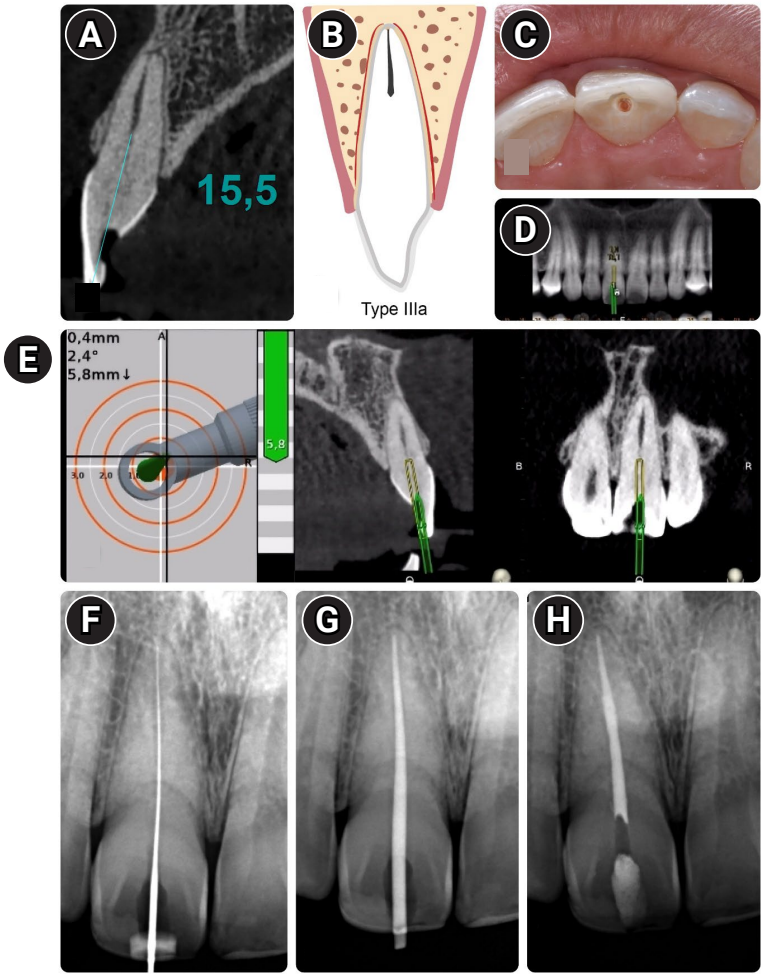


Figure 6. Characteristics of Type IIIa root canal classification. (A) Tomographic image. (B) Type IIIa classification scheme. (C) Access to pulp chamber/root canal. (D) Planning for pulp chamber/root canal access coronal slice. (E) Navident (ClaroNav Inc., Toronto, ON, Canada) graphical interface for root canal access planning. (F) Initial radiograph. (G) Gutta-percha master point fitting before root canal filling. (H) Filled canal.

ed into Navident software to create the respective plan and alignment. Lidocaine 2% with epinephrine 1:80,000 was administered, and canal patency was achieved with a 0.75 mm Tivoli bur. The target point was located 16 mm from the incisal edge. The estimated time to locate the target point was 5 minutes. Mechanical instrumentation was performed using a WaveOne Gold medium file system, and obturation was performed with a cone of the same caliber from the same system and Bio-C Sealer (Figure 6).

6. Classification Type IIIb: Advanced obliteration with severe constriction (middle-third or apical initiation)

• Example 6: A 63-year-old woman with no significant medical history was referred for mild to moderate pain in the upper left central incisor. The clinical examination revealed positive vestibular palpation and percussion, normal periodontal probing, and an adapted crown. Radiographically, the lumen of the partially obliterated canal and apical hypodense area compatible with a periapical lesion are observed. A diagnosis of symptomatic apical periodontitis was made, and apical microsurgery was proposed to the patient as treatment due to an adapted crown and advanced obliteration of the root canal with a high degree of difficulty.

Initially, the area of tooth 11 was anesthetized with two carpules of 2% lidocaine with epinephrine 1:80,000,

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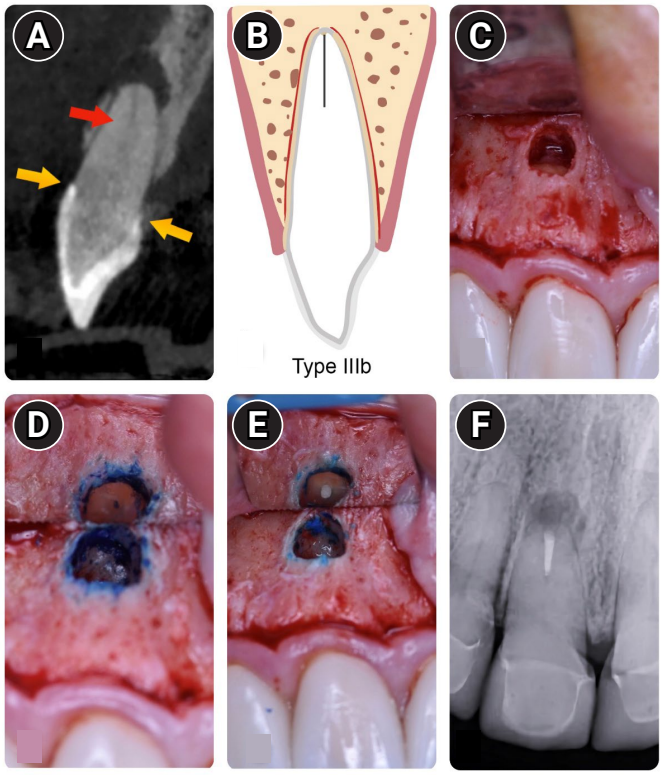


Figure 7. Characteristics of Type IIIb root canal classification. (A) Tomographic image, target point (red arrow), adapted crown (yellow arrows). (B) Type IIIb classification scheme. (C) Access to apex. (D) Root apex outline (methylene blue). (E) Filled root canal with the retrograde filling material. (F) Postoperative periapical radiograph showing root-end fillings.

and a triangular flap was made from tooth 12 to tooth 21. Subsequently, the inflamed tissue was removed, an apicoectomy (3 mm) was performed, and apical retropreparation was made with a diamond ultrasound tip. Finally, the apex was filled with Bio-C® Repair bioceramic reparative material (Angelus Indústria e Comércio Ltda, Londrina, Paraná, Brazil), and the flap was sutured with 5-zero DemeCAPRONE™ synthetic absorbable monofilament suture (DemeTECH Corporation, Miramar, Florida, USA) (Figure 7).

- Example 7: A 36-year-old male patient with intermittent pain in the left lower central incisor with a history of trauma; no medical history. Clinical examination revealed positive vertical percussion and a negative sensitivity test. A CBCT image revealed advanced obliteration of the root canal with diffuse light between the middle and apical thirds. A diagnosis of symptomatic apical periodontitis was made. Due to the level of obliteration and the difficulty of treatment, guided endodontics were performed with dynamic navigation. The DICOM files from diagnostic tomography were imported into the navigation device software Navident, where the orientation and depth of the access path were planned at 15.4mm from the cervical margin to the beginning of the root canal lumen. Canal patency was achieved using a 1-mm Steco bur. Instrumentation was performed with a large file from the WaveOne Gold, and subsequent obturation was performed with a size 45 cone from the same system and Bio-C Sealer (Figure 8).

7. Classification Type IV: Total obliteration with complete radiodensity equivalence

- Example 8: A 40-year-old female patient with no systemic medical history was referred for evaluation and treatment planning for the upper left lateral incisor. Patient with a history of orthodontic treatment. Clinical examination revealed a color change, a negative sensitivity test, and positive horizontal percussion.

Radiographically, a completely obliterated canal and

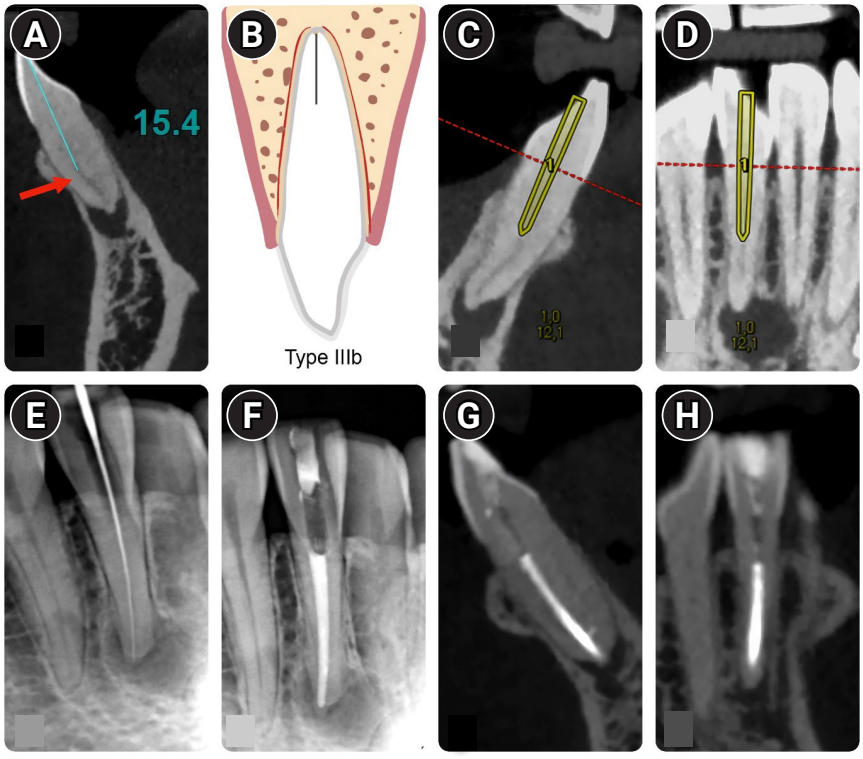


Figure 8. Characteristics of Type IIIb root canal classification. (A) Tomographic image. The red arrow indicates the target point located in the apical third. (B) Type IIIb classification scheme. (C) Planning for pulp chamber/root canal access sagittal oblique slice. (D) Planning for pulp chamber/root canal access coronal slice. (E) Initial root canal negotiation with a file to determine the temporary working length. (F) Filled canal. (G) Filled canal sagittal oblique slice. (H) Filled canal coronal slice.

a healthy periapical region were observed. Pulp necrosis was diagnosed, and the patient was informed of the treatment options (apical microsurgery and guided endodontics). The patient preferred conventional endodontics; therefore, it was decided to perform computer-assisted endodontic treatment. Initially, the DICOM files from the tomography were entered into the Navident for subsequent planning. An access pathway was established along the tooth's long axis to negotiate the root canal lumen at any level, in the absence of a predefined orifice target point. A 0.75 mm Tivoli endodontic bur (Gebr. Brasseler GmbH & Co. KG, Lemgo, Germany) on a low-speed handpiece was used to initiate the opening. The canal lumen was in the cervical third, and the absence of pulpal vitality was confirmed. The canal was instrumented with a primary file from the WaveOne Gold and obturated with a cone of the same system and AH Plus. The patient was then referred for restorative treatment (Figure 9).

DISCUSSION

The cases presented above propose an exhaustive and exclusive classification of the state of obliterated or calcified root canals based on the location of the target-point and the visible caliber on radiographs and/or tomography with a clinical focus and negotiation of ducts by guided endodontics. In this context, it is important to highlight that Lima et al. [15], in 2024 in a bibliometric review [15], mention that from the first publication on this topic in 2016 by Krastl *et al.* [16], the prevalent focus of research has been the static navigation technique and that it was the negotiation of calcified ducts that has given rise and development of the technique.

The documentary collection on the effectiveness and efficiency of guided techniques is constituted, for the most part, by numerous case reports and case reports whose evidence indicates that guided endodontics is

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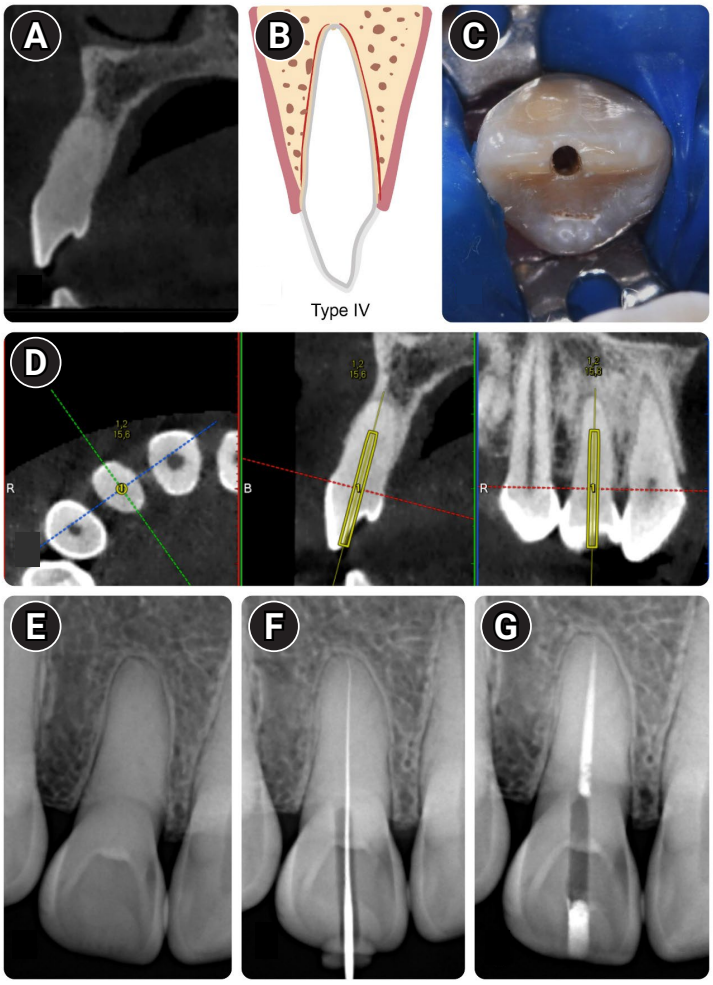
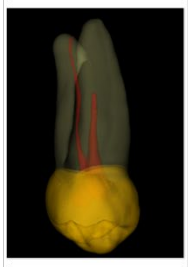


Figure 9. Characteristics of Type IV root canal classification. (A) Tomographic image. (B) Type IV classification scheme. (C) Access to pulp chamber/root canal. (D) Navident (ClaroNav Inc., Toronto, ON, Canada) graphical interface for root canal access planning. (E) Initial radiograph. (F) Initial root canal negotiation with a file to determine the temporary working length. (G) Filled canal.

a technique with high precision and with the capacity to predict the outcome of the intervention [17]. However, there is a gap in the evaluation of efficacy given the limited number of high-quality clinical trials with long-term follow-up [15,17]; the available studies are affected by the heterogeneity of the outcomes [17,18], absence of standardized protocols, the difficulty in the proper selection of cases with particular indications for each technique [15] and lack of consensus in essential aspects of endodontic therapy [18]. It is in this sense that the scientific community has directed efforts in the determination of taxonomies that allow us to define in a precise and practical way characteristic aspects of the conditions and outcomes in health [19,20].

In 2024, Terán-Miranda [21] makes a very detailed classification proposal of the level and degree of calcification where ten levels are recognized according to the identification zone of the calcification (pulpar, cervical, middle, apical, pulpar + cervical, cervical + middle, middle apical, pulpar + cervical + middle, cervical + middle + apical and total) and four degrees (permeable, obliterated, intermittent, closed)which in the context of studies with an analytical approach can favor type II error due to the number of subgroups resulting from the combination of its two components. In contrast, the current proposal defines a total of seven categories on an ordinal scale because of the challenge of reaching the target point and the negotiation of the root canals

3D Diagram	Description	Adaptation
	Left maxillary central incisor, uniradicular with pulp canal obliteration classification IIa (Partial obliteration of the root canal that begins between the CEJ and the middle third of the root)	$(PCo)^{IIa}\ ^{1}21^{1}$
	Right maxillary first premolar, biradicular with obliteration of the buccal pulp canal, classification Ia. (Presence of canal lumen above the CEJ with obliteration in the cervical, middle and apical root thirds) in buccal root Ib. (Advanced obliteration of the root canal that begins in the crown above the CEJ)	$(PCo)^{2}\ 14\ B^{1(Ib)}\ P1^{(Ia)}$
	Lower right second molar, biradicular with distal root dilaceration and obliteration in mesial pulp canal with classification IV. (Total obliteration of the root canal)	$(PCo)^{2}\ 47\ M^{(RD)}\ D^{(IV)}$

*International tooth numbering system (FDI)

Figure 10. Adaptation to the nomenclature of classification of morphological anomalies. 3D, three-dimensional; CEJ, cementoenamel junction; FDI, Fédération Dentaire Internationale; PCo, pulp canal obliteration.

according to the caliber.

Another important aspect is the easy adaptation to the nomenclature of classification of morphological anomalies proposed by Ahmed and Dummer [22] by prefixing pulp canal obliteration (PCo) and classification in superscript to the number of the dental piece, in those uniradicular and/or multiradicular teeth in which the classification of the root canal coincides. In case of disagreement, PCo is prefixed to the tooth number and the classification in superscript is added for calcified root canals present [20,22–25] (Figure 10).

While the limitations of images obtained via CBCT should be considered (difficulty in detecting accessory canals and minor anatomical variations), their use is recommended for applying the classification, as their influence on the decision regarding the complexity or difficulty of endodontic therapy is recognized [26], especially in cases where the morphological characteristics of the root canal system pose a challenge for diagnosis, prognosis, and therapeutic approach; their use is even recommended for the evaluation of clinical results [27,28]; however, it is important to emphasize the possibility of using high-quality radiographic images, which favors the implementation of the classification in regions where the availability of obtaining CBCT images is limited; furthermore, the simplicity and conciseness in the definition, as well as the adaptation to the Ahmed scheme, can be taught and adopted from undergraduate and postgraduate professional training [24,29].

The conventional technique for locating canals allows the location of the root canals, but requires excellent spatial location, magnification, and ultrasonic tips [8]. Recent reports have shown that new navigation techniques in endodontics are usually more accurate and require less clinical working time [11,30–34]. Connert *et al.* [10] in 2019 report the results of an *in vitro* study that indicates that static navigation was significantly superior to the conventional technique, even consider-

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ing that it was used by operators with different levels of experience; similarly, clinical cases have been reported to have been performed with static navigation with high accuracy for locating calcified canals [35,36].

Villa *et al.* [34] reported two clinical cases approached with dynamic navigation in anterior teeth, achieving a high degree of precision and conservative accesses with the use of the Navident; in 2020, Jain *et al.* [37] performed an *in vitro* study with 40 upper and lower anterior teeth printed in three-dimensional, where the dynamic navigation technique proved to be more efficient and faster for locating obliterated canals. Gambarini *et al.* [38] also reported a case of apical surgery in an upper anterior tooth with the help of the Navident system, achieving optimal precision. Zubizarreta-Macho *et al.* [11] conducted a study comparing the conventional technique with the two types of navigation (static and dynamic) and observed that the latter had better performance when comparing the previous planning versus the execution, locating the lumen of the root canals. They concluded that although dynamic navigation is more precise than static navigation, there was no statistically significant difference in loss of dental tissue after opening.

Geo *et al.* [12] reported that the main advantages of dynamic navigation are greater accuracy, no need for patient scanning, simpler planning process, better instrument access due to the absence of guides, visualization of the access path in real-time, and the possibility of changing or correcting the plan at any time.

It can therefore be concluded that, according to the results presented, the two techniques present very similar results in terms of accuracy and predictability for locating obliterated canals [11,12]; however, the complexity of these treatments with any type of navigation can vary depending on the location of the target point or the beginning of the root canal lumen and their caliber. Clinically, a narrow canal located in the apical third of the root could be much more complex to locate than a canal that starts above the middle third of the root. Studies that analyze and compare the complexity of the procedures according to these clinical characteristics have not been conducted.

CONCLUSIONS

A classification system comprising eight types of calcified root canals was proposed, categorized by the degree of obliteration and the anatomical location of the canal's "target point" along the root axis. This taxonomy offers significant clinical utility for the planning and execution of endodontic treatment protocols, particularly concerning access and exploration of the root canal system.

Furthermore, the analysis of the presented clinical cases elucidates the distinct characteristics of each category while simultaneously highlighting the effectiveness of guided techniques (static and dynamic) as preferred strategies for managing obliterated canals.

This framework is positioned to serve as a valuable didactic resource in both undergraduate and postgraduate training, enabling students to grasp the inherent complexities of these cases and facilitating informed decision-making regarding referral and counter-referral pathways. Moreover, this system contributes substantially to the taxonomic resources available for future research concerning the prevalence, prognosis, and treatment strategies associated with this variant of the root canal system.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTIONS

Conceptualization: Castillo Barrios GA, Rodríguez Sánchez P, Barona Triviño AE; Formal analysis, Investigation: all authors; Supervision, Visualization: Martínez Cajas CH; Writing - original draft: all authors; Writing - review & editing: all authors. All authors read and approved the final manuscript.

DATA SHARING STATEMENT

The datasets are not publicly available but are available from the corresponding author upon reasonable request.

DISCLOSURE OF GENERATIVE AI IN SCIENTIFIC WRITING

The authors used DeepL (DeepL SE, Cologne, Germany) and Claude (Anthropic PBC, San Francisco, CA, USA) to check the grammatical structure of the English in the draft while preparing this paper. After using these tools, the authors reviewed and edited the content as necessary and assume full responsibility for the content of the publication.

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