CASE REPORT OPEN ACCESS

Guided Cavity Preparation to Access an Invagination and Preserve Pulp Vitality of an Immature Maxillary Lateral Incisor With Type IIIa Dens Invaginatus: Technical Overview and a Case Report With 3-Year Follow-Up

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Received: 23 October 2025 | **Revised:** 25 November 2025 | **Accepted:** 9 December 2025

Keywords: case report | cone beam computed tomography | dens invaginatus | guided endodontics

ABSTRACT

Aim: Dens invaginatus (DI) is a developmental anomaly often associated with caries and periapical pathosis. This report describes guided access and filling of an infected invagination in a maxillary lateral (tooth #22) with long-term preservation of pulp vitality.

Summary: A 9-year-old male presented with a palatal sinus tract associated with immature tooth 22. Based on clinical and radiographic examination, a type IIIa DI with a pseudo-foramen midway along the mesial aspect of the root was identified. The tooth had a healthy pulp and peri-invagination periodontitis. A guided endodontic cavity was prepared to selectively access the invagination without compromising the pulp and the invagination filled with a bioceramic calcium silicate–based material. At 36 months the tooth was asymptomatic, and the pulp tested positive. Radiographically, root development was complete with bony healing of the lesion. This case report highlights the effectiveness of guided cavity preparation to access an invagination in an immature tooth with DI while preserving pulp vitality.

1 | Introduction

Dens invaginatus (DI), previously known as dens in dente, is a malformation caused by the infolding of the enamel organ into the dental papilla during tooth development prior to calcification (Alani and Bishop 2008; Siqueira et al. 2022). Factors such as trauma, infection as well as genetics are linked to the development of the anomaly. The prevalence of DI is approximately 7% with maxillary lateral incisors being more commonly affected with a unilateral prevalence of 5% (Dos Santos et al. 2023). Among the types of DI, Type 1 is the most common (Dos Santos et al. 2023). Based on the extent of the invagination, clinical characteristics of DI vary from a relatively normal crown to one with an altered morphology, such as barrel-shaped or dilated with a bifid cingulum (Siqueira et al. 2022; Zhu et al. 2017).

An invagination is an enamel lined pseudo-canal with frequent deficiencies in the lining resulting in communication with dentine and pulp tissue (Hülsmann 1997). Prior to eruption into the oral cavity, enamel epithelium or dental papilla remnants fill the invagination, however, post eruption, this is replaced with food debris and microorganisms (Rushton 1958). The proximity of the invagination to the pulp as well as bacterial colonisation associated with debris accumulation increases the risk of caries and subsequently pulp and periapical pathosis. Oehlers classified DI into the several categories based on the extension of the invagination and its link to the periodontal ligament (Oehlers 1957). In type I, the invagination is restricted to the crown of the tooth; in type II, the invagination passes down the root and terminates in a 'blind sac' that may or may not communicate with the pulp; in type IIIa, the invagination extends below the cementoenamel junction and connects laterally with the periodontal ligament through a pseudo-foramen, whereas in type IIIb, the invagination extends apically and connects with the periodontal ligament through the apical foramen (Oehlers 1957).

The treatment strategy for teeth with DI is determined by the extent of the invagination, pulp status, periapical condition and stage of root development. However, early diagnosis of DI aided by advanced imaging techniques like cone beam computed tomography (CBCT) and filling of the invagination is recommended for all cases. Presence of a healthy pulp during the diagnostic stage suggests that disinfecting and filling only the invagination is an appropriate therapeutic option as it will preserve pulp health.

The recently described therapeutic options of using three dimensional (3D) templates/guides have been suggested for access to and filling of the invagination (Ali and Arslan 2019; Li et al. 2024). These three-dimensional printed guides provide precise access to the invagination and avoid excess dentine removal or accidental entry into the root canal (Ali and Arslan 2019). Guided endodontics integrates the use of CBCT imaging and digital scanning of the tooth to design and print templates for precise placement and alignment of drills to reach the intended target (Li et al. 2024). However, use of guided templates for filling the invagination and preserving pulp health is under-reported. Preserving the health of the pulp will allow completion of root development in teeth with immature apices associated with DI.

This case report highlights the use of advanced imaging techniques and printed guides when gaining access to an invagination and preserving pulp health of an immature maxillary left lateral incisor (FDI: tooth 22) with a Type IIIa DI.

2 | Case Description

The case report follows the Preferred Reporting Items for Case reports in Endodontics (PRICE) 2020 reporting guidelines (Nagendrababu et al. 2020). The main stages of the case are illustrated in the PRICE flowchart (Figure S1).

A 9-year-old male was referred in 2022 by a general dental practitioner for an opinion and management of a persistent palatal sinus tract in the maxillary anterior region. The patient reported a history of occasional discomfort and a transient episode of palatal swelling a few weeks earlier, which resolved spontaneously. The patient's medical history was non-contributory with no history of dental trauma, caries, or previous endodontic treatment. The patient had been undergoing orthodontic treatment for a Class I malocclusion for 1 year, during which a continuous light force was applied to tooth 22. Clinically, tooth 22 had fully erupted and its crown was wider in comparison to tooth 12. Canine guidance was still in the process of developing and no occlusal interferences involving tooth 22 were present. The tooth was tender to percussion and had a palatal swelling and sinus tract (Figure 1a). There were no associated pathological periodontal pockets, and the tooth exhibited normal physiological mobility. Radiographically, tooth 22 had an immature apex with an invagination extending to the middle third of the root and an area of reduced bone density on the mesial aspect of the root. At this stage it was not clear whether this represented a periradicular lesion or the radiographic appearance of the mesial root contour (Figure 1b). Thermal and electric pulp sensibility tests were positive.

To further assess the complexity of the anatomical variation as well as to formulate a treatment plan a CBCT scan was acquired. The CBCT images revealed that the bucco-lingual dimension of the crown and root of tooth 22 were larger in comparison to the adjacent teeth. The invagination extended mesially up to the mid-root and the main canal was displaced laterally and compressed to a C-shape with no communication evident between the invagination and the root canal. The diameter of the invagination was 0.80 mm. The invagination communicated with the periodontal ligament with a well-defined bone defect mesio-palatally. The bony lesion had expanded to breach the cortical plate palatally. The CBCT periapical index (CBCTPAI) (Estrela et al. 2008) was scored as 4D, indicating a periapical lesion with palatal cortical plate perforation (Figure 1c–e). Based on the clinical and radiographic findings, the tooth was diagnosed as Type IIIa dens invaginatus with associated peri-invagination periodontitis, while the pulp was considered healthy.

To preserve pulp health, a guided endodontic approach was planned and discussed with the patient and guardian. Written informed consent and verbal assent were obtained prior to treatment. For publication of this case report (including clinical information and images) consent was obtained from the patient's parents. An intraoral digital impression was taken using an intraoral scanner (i700 scanner; Medit Corp., Seoul, South Korea), and the resulting STL file was imported into implant planning software (Blue Sky Plan; Blue Sky Bio, Libertyville, IL, USA) and merged with the DICOM dataset from the CBCT scan (Figure 2a,b). A virtual drill path was designed to selectively access the invagination while avoiding the canal (Figure 2c–f). A tooth-supported 3D guide was fabricated using a desktop 3D printer (Form 3B+; Formlabs Inc., Somerville, MA, USA) with biocompatible surgical resin (Surgical Guide Resin; Formlabs Inc), providing a precise and minimally invasive access channel (Figure 3a).

The 3D-printed guide was verified intraorally for stability and accuracy of fit prior to local anaesthesia administration and rubber dam isolation (Figure 3b). Anaesthesia was obtained using 0.6 mL of 2% lidocaine (Lidocaína Normon 2%; Laboratorios Normon, Madrid, Spain) using a buccal

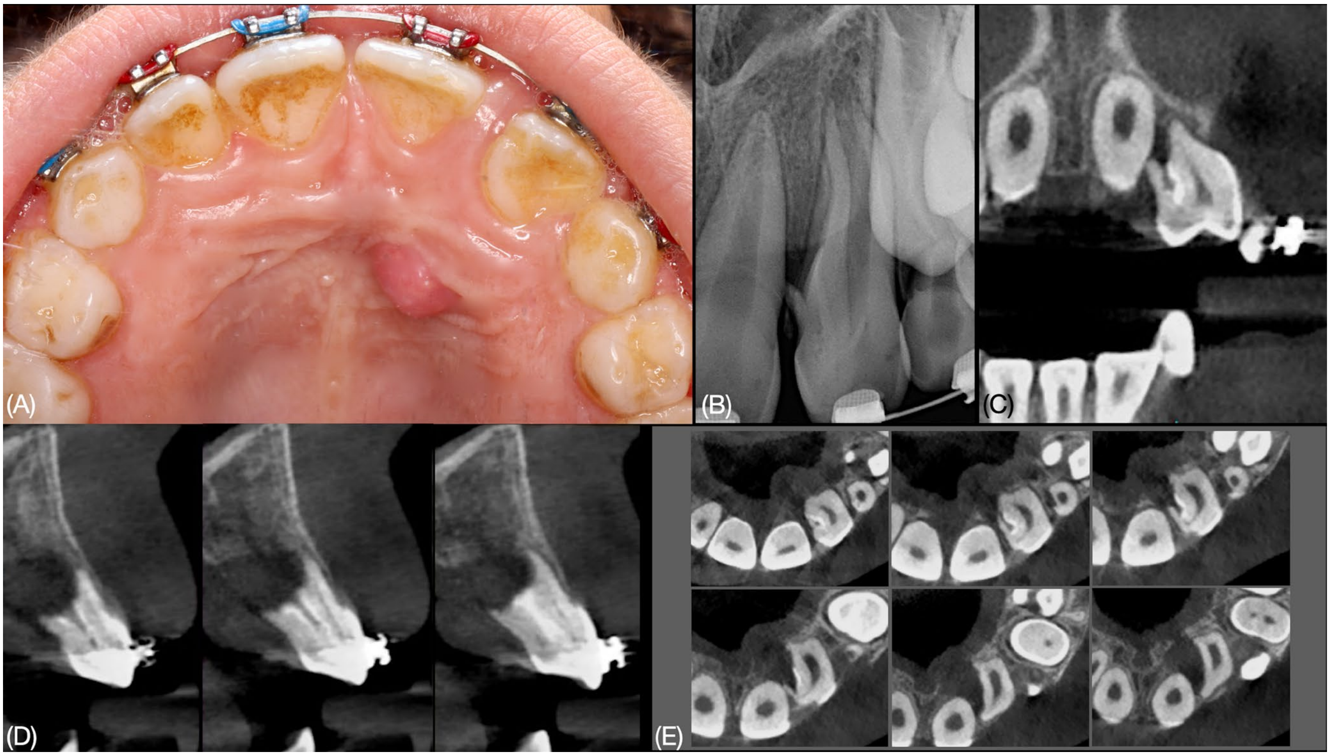

FIGURE 1 | Clinical and radiographic images of a maxillary left lateral incisor (tooth 22) with Type IIIA dens invaginatus. (A) Intraoral photograph showing the palatal swelling associated with tooth 22 consistent with a chronic apical abscess. (B) Periapical radiograph revealing the invagination on the mesial aspect of the root of tooth 22, while the root canal and the apical PDL appear normal for an immature apex. (C) CBCT coronal and sagittal views showing a Type IIIA dens invaginatus according to Oehlers classification, with a pseudo-foramen lying mesially beyond the cemento-enamel junction. (D) Sequential sagittal CBCT slices illustrating the trajectory and lateral communication of the invagination. (E) Axial CBCT slices confirming the complexity and independence of the invagination from the root canal system.

infiltration over the mucobuccal fold of tooth 22. The superficial 2 mm of enamel was removed using a small round diamond bur to create a reference point and facilitate guided entry. This step provides a stable and reproducible entry site, reducing the risk of the pilot bur slipping on the smooth enamel surface and ensuring accurate guidance and angulation during drilling. Subsequently, guided access to the invagination was performed using the printed template and a 21-mm long, 0.75-mm diameter drill (FFDM-Pneumat; Tivoly, Bourges, France), which is a long-shank bur designed for precision access in guided endodontics, under copious water irrigation and high-speed rotation. The small-diameter drill was selected to allow a minimally invasive and accurate penetration toward the invagination while avoiding the root canal. Chemomechanical disinfection of the invagination was carried out using 2.5% sodium hypochlorite (NaOCl) delivered through a negative pressure irrigation system (EndoVac; Kerr Endodontics, Orange, CA, USA). The irrigation protocol included copious irrigation with 2.5% NaOCl, followed by 17% liquid EDTA (Vista Dental, Racine, WI, USA) for 1 min to remove the smear layer, and a final rinse with 96% ethanol to dry the walls of the invagination. Agitation of the irrigants was performed with an ultrasonic tip (IRRI 15 K; Satelec Acteon Group, Mérignac, France) to enhance their action. The apical extent of the invagination was gauged with a size 80 K-file (Dentsply Maillefer, Ballaigues, Switzerland) to confirm patency and working length; however, no further mechanical shaping or enlargement of the invagination was performed. The 0.75-mm guided drill (FFDM-Pneumat; Tivoly, Bourges, France) was used only to create the minimally invasive access and was advanced to the pre-planned depth as controlled by the printed template and the drill's physical depth stop. The 21-mm overall length of the drill refers to the instrument length; however, the actual penetration during the procedure was limited by the template and care was taken not to extend into or beyond the external root surface or periodontal tissues.

After drying, the invagination was filled using a premixed bioceramic calcium silicate–based material during the same visit (NeoPutty; Avalon Biomed, Houston, TX, USA). The access cavity was subsequently restored with resin composite (Figure 3c–e).

Follow-up evaluations were conducted at 1 week, 6 months, 1 year and 3 years (Figures 3f,g and 4a,b). The patient remained asymptomatic, with no pain or swelling. The tooth was not mobile, and the palatal sinus tract had healed. Pulp health was confirmed at all follow-ups using both thermal and electric tests. Radiographic assessment demonstrated progressive bony healing of the periapical lesion, with no evidence of persistent pathosis. Notably, narrowing of the root canal width was observed at the 36-month follow-up, indicating preservation of pulp health and continued root development (Figure 4b).

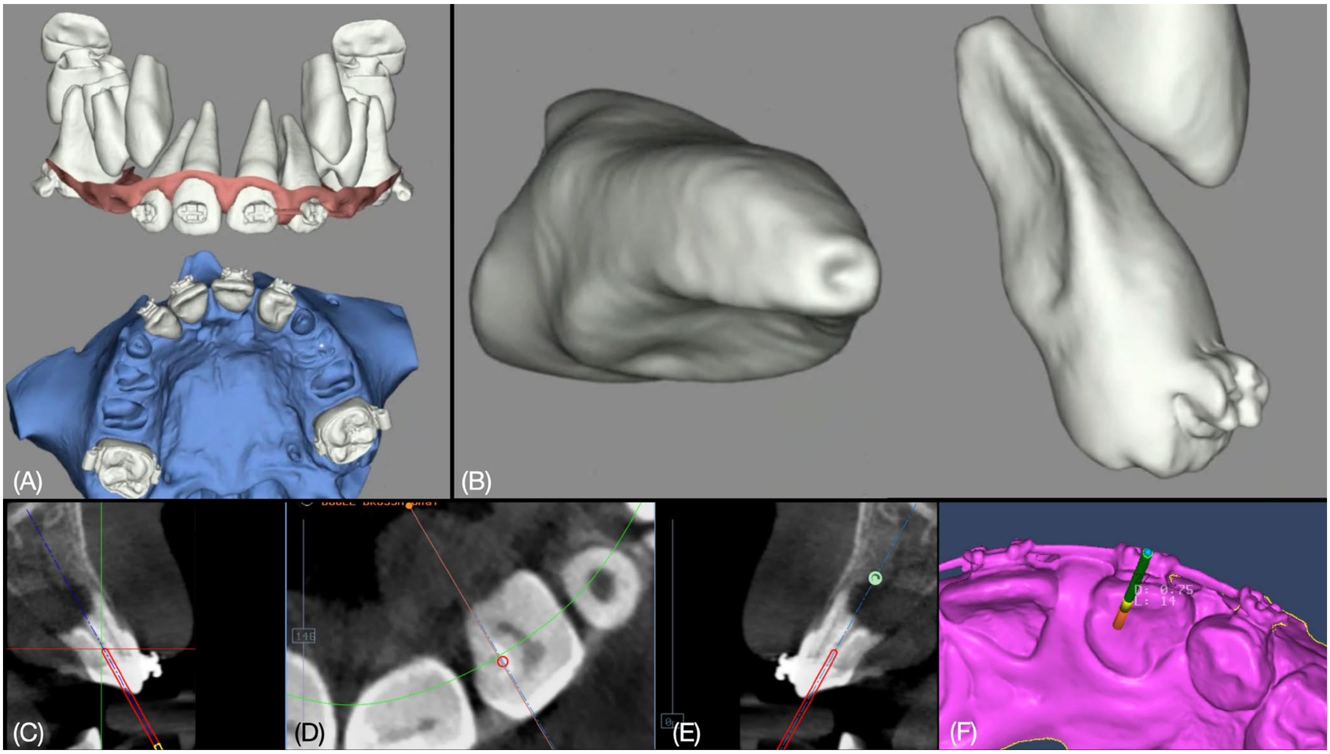

FIGURE 2 | Digital workflow for planning guided access to enter the invagination while avoiding the root canal. (A) Integration of intraoral scan and CBCT data showing segmentation of the teeth and supporting structures. (B) 3D renderings of the invagination illustrating its irregular shape and spatial isolation. (C–E) Multiplanar CBCT views (cross-sectional, axial and sagittal) depicting the planned drill path exclusively targeting the invagination. (F) Final planning view showing the ideal access trajectory, avoiding entry to the root canal.

3 | Discussion

The diagnosis and treatment plan of teeth with DI is determined by the relationship of the periradicular lesion with the invagination, the root canal, or both. The application of CBCT with a limited field of view as a supplementary method for the diagnosis and treatment planning of teeth with these developmental anomalies, particularly in young patients, is recommended by the American Academy of Oral and Maxillofacial Radiology (AAOMR) and the American Association of Endodontists (AAE) Joint Position Statement (AAE and AAOMR Joint Position Statement 2015) The use of CBCT has increased annually in the age group of 6 to 12 years (Yiğit et al. 2023), which, according to a cross-sectional study, could be due to the fact that clinicians have become more aware of the availability and advantages that detailed CBCT images offer in aiding diagnosis and management (Yiğit et al. 2023). Consequently, in the present case report, a preoperative CBCT assessment was performed to ascertain the position and path of the invagination, the type of invagination and its relationship to the apical pathosis and root canal.

In the current case, periapical radiographs did not allow a definitive distinction between periodontal bone loss associated with the invagination and a true apical lesion related to the root canal. Therefore, a CBCT scan was obtained for further assessment. CBCT revealed a localised radiolucent tract on the mesiopalatal aspect adjacent to the invagination that extended toward the apical region; importantly, no clear radiographic communication between the lumen of the invagination and the root canal/pulp chamber was identified on the CBCT slices.

A clinical case report confirmed that treatment of the invagination of a mandibular central incisor with type III DI and peri-invagination periodontitis maintained the health of the pulp (Lee et al. 2020). However, a case report by Zargar et al. (2023) demonstrated that one of the bilaterally treated DIs failed at the one-year follow-up and required root canal treatment even though the treatment was intended to preserve pulp vitality. In the present case, the peri-invagination disease healed while the pulp's vitality was preserved. This conservative and targeted approach is also more beneficial in terms of tooth integrity than more radical root canal treatment and may also be associated with a reduction in the incidence of future root fracture (Kamio et al. 2021). This report also underscores the importance of assessing pulp status in DI teeth, even when a bony defect is evident radiographically. The detection of a viable pulp within the root canal enabled the treatment approach to focus solely on the invagination. Maintaining pulp vitality prevented unnecessary removal of root canal dentine and helped retain moisture within the dentinal tubules, thereby enhancing the fracture resistance of the tooth.

In the current report, the drill was prevented from extending beyond the root surface or damaging periodontal tissues, by ensuring (a) resin sleeve height adjustment: (b) predetermined drill penetration depth: (c) integrating the drill with a stopper. The risk of perforation into the pulp was mitigated by employing 3D printed guides to align the drill and thus precisely access the invagination. The templates were personalised in comparison to several DI cases using the guided endodontics approach, as influenced by the 3-determination

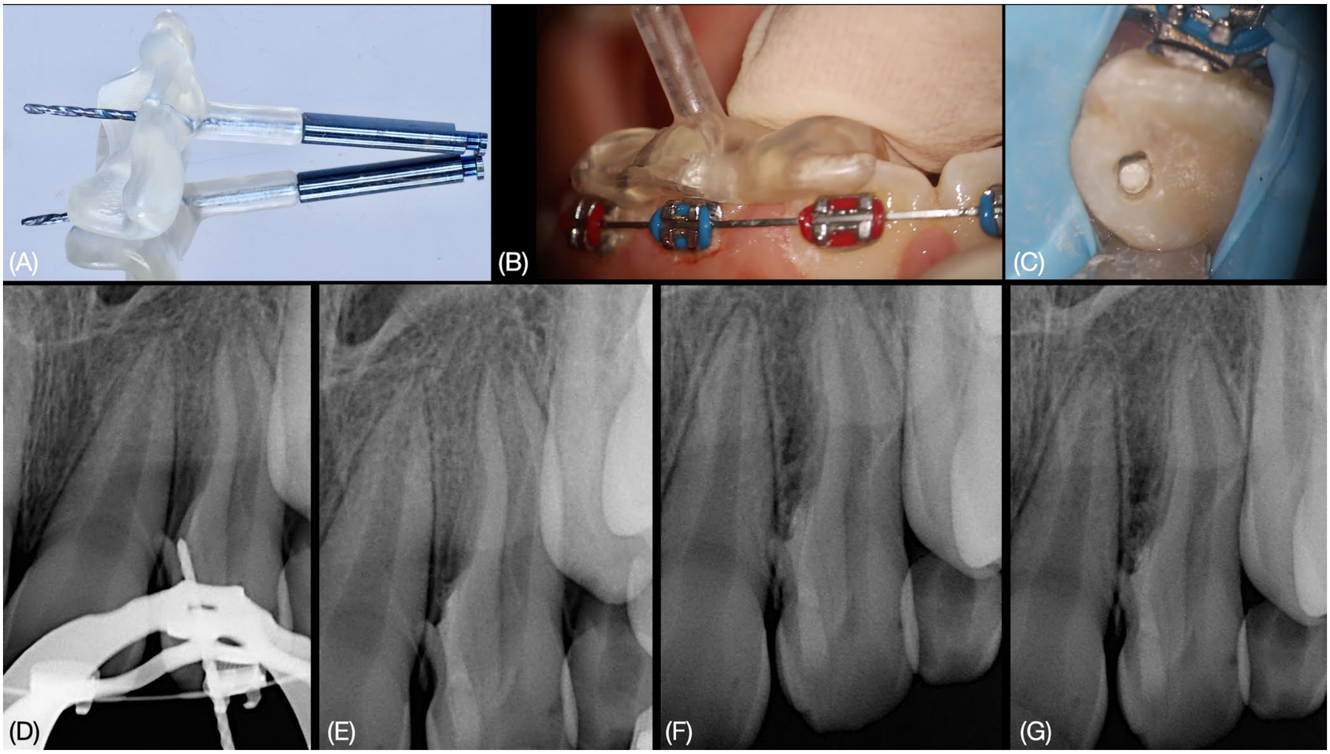

FIGURE 3 | Clinical execution of the guided access and radiographic follow-up after filling the invagination. (A) 3D-printed static guide without metallic sleeves, used with a 0.75 mm diameter, 21 mm length drill (FFDM-Pneumat; Tivoly, Bourges, France). (B) Intraoral view showing the guide in position, allowing a minimally invasive trajectory to selectively access the invagination while avoiding the root canal. (C) Occlusal view of the invagination filled using a premixed calcium silicate-based hydraulic cement (NeoPutty; Avalon Biomed, Zarc4Endo, Houston, TX, USA). (D) Working length determination confirming successful negotiation of the invagination. (E) Immediate postoperative radiograph following filling of the invagination. (F) Six-month follow-up radiograph showing signs of continuing root development and healing of the mesial lesion on tooth 22. (G) One-year follow-up radiograph demonstrating complete resolution of the lesion and no apical pathosis.

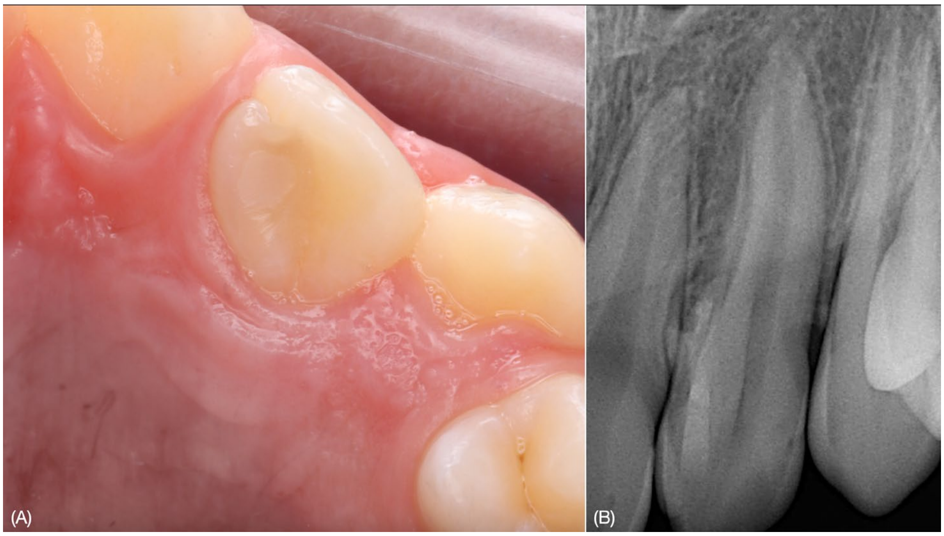

FIGURE 4 | Long-term clinical and radiographic follow-up confirming healing and tooth tissue preservation. (A) Intraoral clinical view at the 3-year follow-up, showing normal palatal soft tissues and a sound maxillary left lateral incisor. (B) Periapical radiograph at the 3-year follow-up, demonstrating mesial bone regeneration, continued root development and absence of periapical pathosis.

principle, which includes determination of the location, depth, and instrumentation angle in the management of calcified root canals (Ali and Arslan 2019; Ali et al. 2019). In addition to ensuring that the access location and direction were correct, the optimal operating depth was also controlled by modifying the height of the resin sleeve in the template. This additional control during drilling is particularly beneficial for clinicians who are less experienced, as it minimises uncertainty during the procedure and enables the preservation of the maximum amount of tooth tissue (Li et al. 2024). The previous application of guided endodontics to preserve pulp health in teeth with DI was conducted in a type II DI case (Ali et al. 2019) whereas the patient in the present case had a type IIIa DI. The guided approach used in this case offers high precision, as the intraoral fit of the guide was verified prior to drilling, ensuring an accurate transfer of the planned trajectory to the clinical situation. This aligns with previous studies that reported low linear and angular deviations (Zehnder et al. 2016). However, limitations inherent to static-guided endodontics such as errors in CBCT acquisition, intraoral scanning, or during data merging may lead to deviations between virtual planning and clinical execution (Moreno-Rabié et al. 2020).

Within the context of this particular case, 2.5% NaOCl was delivered using an Endovac device to combine the antimicrobial efficacy of the irrigant with the reduced risk of apical extrusion because of its apical negative irrigation functionality. It is well-established that the antibacterial activity of NaOCl is dose-dependent; higher concentrations (e.g., 5.25%) were not used due to the immature apex of tooth 22. The intermediate concentration of 2.5% NaOCl provides effective antimicrobial and tissue-dissolving properties with reduced cytotoxicity (Mohammadi 2008) and has been used in paediatric patients for routine endodontic procedures (Valizadeh et al. 2024). In the present report, irrigation was conducted utilising an apical negative-pressure system (EndoVac). Magni et al. (2021) observed that negative-pressure irrigation (i.e., EndoVac) generated the lowest apical pressures, thereby substantially decreasing the risk of irrigant extrusion when compared to positive-pressure systems in an open apex maxillary central incisor model. Similarly, a systematic review concluded that Endovac decreased extrusion relative to conventional irrigation and is regarded as safe (Romualdo et al. 2017).

The key concept of debridement for an invagination is to accomplish optimum efficiency with minimal tooth tissue loss. The MICRO principle, which encompasses the following important aspects, can be used to guide this principle: the maximum mechanical debridement (M); the maximum amount of chemical irrigation (I); access cavity (C) that is both ideal and precise; the rectilinear (R) path that is most expedient; and minimal obstruction (O) (Li et al. 2024). Adjunctive irrigation is recommended to enhance the cleaning of complex invaginations. Endodontic instruments may not be able to enter certain regions of an invagination, necessitating the use of large volumes of NaOCl solutions activated by an irrigation device (Li et al. 2024). Although gutta-percha and a sealer are typically employed for filling canals after their preparation, bioceramics are the preferred choice when the apical morphology of the root canal is complex (Lee et al. 2020). In various case reports, gutta-percha has been employed in conjunction with zinc oxide or bioceramic sealer to fill invaginations (Kamio et al. 2021). Due to the wide apical diameter of the invagination (0.8 mm), achieving a reliable apical stop for a gutta-percha point was not feasible. Therefore, a bioactive tricalcium silicate cement was used to fill the entire invagination. The material was introduced incrementally under an operating microscope and compacted gently with a Machtou plugger (Dentsply Sirona, Ballaigues, Switzerland) to prevent extrusion beyond the pseudo-foramen. The viscous consistency of the putty-like material also allowed precise adaptation to the walls of the invagination and a homogeneous fill. Tricalcium silicate cements are bioactive, produce calcium hydroxide as a byproduct of hydration, and promote the deposition of hydroxyapatite when in contact with tissue fluids (Camilleri et al. 2013). Although only a few reports have described complete filling of the invagination with such materials, this approach was considered suitable for this case (Lee et al. 2020; Ali et al. 2019).

In the current case the pulp was vital at the baseline clinical evaluation and also throughout the procedure. Hence, the peri-invagination periodontitis was unrelated to the orthodontic treatment and the sinus tract was a result of peri-invagination periodontitis. Hence, the combination of the pulp being vital, which retains its natural defence mechanism, with the use of the MICRO principle for disinfection of the invagination allowed the entire treatment to be completed in a single visit. At follow-up, the sinus tract had resolved, and the pulp remained vital, confirming the success of the single-visit treatment.

The limitation of this report is that it documents a single case, and future validation of the technique with multiple cases or larger sample sizes is necessary. However, the rare occurrence of such a clinical scenario, where the pulp remains vital in a deeply invaginated tooth, may restrict the applicability of such study designs. The strength of this report is the application of 3D guided access and the long-term follow-up (36 months). However, ongoing periodic assessments of the status of the tooth will be undertaken over time.

4 | Conclusion

The conservative and targeted access and filling of an invagination in tooth 22 with a type IIIa DI and the maintenance of pulp health were successfully achieved through the use of a guided approach. The invagination was negotiated, debrided and filled effectively, whilst avoiding iatrogenic damage to the pulp and retaining the maximum volume of tooth tissue. The approach also saved chairside time, increased procedural accuracy, minimised patient discomfort and preserved pulp health.

Author Contributions

Francesc Abella Sans conceived the clinical concept, performed the clinical procedures, collected the case data and drafted the manuscript. Venkateshbabu Nagendrababu contributed to the draft and made critical revisions of the manuscript. Nandini Suresh contributed to the draft and made critical revisions of the manuscript. Marc Garcia-Font assisted in manuscript revision. Paul M.H. Dummer critically reviewed and refined the manuscript. All authors approved the final manuscript and agree to be accountable for all aspects of the work.

Funding

The authors have nothing to report.

Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** PRICE 2020 flowchart.