Treatment opinions for dens invaginatus: A case series

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Abstract. Dens invaginatus (DI) is a rare congenital dental malformation characterized by enamel or cementum folded into dentine. Such teeth are susceptible to caries, pulp infection or necrosis and periradicular lesion. The complex anatomy of this disease results in difficult treatment and a high rate of therapeutic failure. Therapeutic options, such as debriding and filling invagination, root canal treatment (RCT) and intentional replantation, vary according to the morphology and infection of the involved tooth. The present study reports five cases of DI with chronic apical periodontitis. The treatment strategies and procedures, including RCT, removing the invagination, intentional replantation and surgical treatment, are discussed according to the classification and the condition of pulp and periapical tissue. The study also reports the prognosis: All patients were followed up for ≥12 months and all teeth demonstrated periapical healing and clinical asymptomatic. In summary, appropriate treatment is based on accurate analysis of the anatomical variation in different types of DI and intentional replantation is a reliable and viable treatment to preserve the tooth.

Introduction

Dens invaginatus (DI), also called dens in dente, is a developmental malformation due to an invagination of the enamel organ into the dental papilla during the morpho-differentiation phase of tooth development (1,2). DI can occur in both deciduous and permanent dentition but is more common in permanent dentitions, with a prevalence of 0.04-10.00% (3-5). The maxillary lateral incisor is the most frequently involved tooth for DI and there are also reports that DI occurred in canines and posterior teeth (6-8). DI may also uncommonly occur in supernumerary teeth (5). Several etiopathogenic theories have been proposed to explain the development of this malformation: Focal failure growth of the internal enamel epithelium engulfed by surrounding continuous proliferating dental papilla cells is one of the causes of DI (9). Oehlers considered that during tooth development the enamel organ distortion induces protrusion of the enamel organ into the dental papilla, which may lead to invagination (10). In addition, external forces from adjacent teeth, trauma, infection and genetic factors also are considered as possible contributing factors (6,11).

According to the origin of invagination, the anatomical disorder is classified into two categories: Coronal and radicular DI (CDI and RDI, respectively) (10,12). Oehlers proposed three types of CDI malformation (10): Type I, invagination is lined by enamel and within the confines of the crown not extending beyond the amelocemental junction; type II, invagination extends into the root, beyond the cementoenamel junction and ends as a blind sac, with or without communicating with the dental pulp and type III, invagination extends to the root, forming an additional pseudo apical or lateral foramen in the apical or periodontal area, usually with no communication with the pulp. RDI occurs due to invagination of Hertwig's sheath into the developing root. There are two subtypes of RDI: Type I, invagination is cementum-lined and related to an axial root groove; and type II, enamel-lined invagination within the root (12).

Due to deep pits and structural defects, teeth with DI are more susceptible to caries, pulpitis, pulp necrosis, periapical lesion and even periodontal diseases (13-16). The complex structure increases the difficulty of diagnosis and treatment of DI. The radiographical imaging of DI often shows a radiolucent invagination surrounded by a radiopaque area (enamel) in the tooth crown or extending into the root (1). Although two-dimensional (2-D) radiographs are routinely used to diagnose DI, treatment of complicated cases requires three-dimensional (3-D) radiographical imaging, such as cone-beam computed tomography (CBCT). CBCT is a well-established 3-D imaging technique that has several superiorities over 2-D radiographs, including superior diagnostic ability in detection of DI and assessment of its type (8,17). In addition, CBCT provides more accurate images of periapical lesions than periapical or panoramic radiographs (18). Therefore, CBCT instead of 2D radiographs can assist in the diagnosis and treatment of DI.

The principle underlying treatment for DI should be maintaining the pulp vitality and preserving tooth structure using

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minimally invasive methods (8). Various treatment options, including prophylactic filling, root canal treatment, the combination of endodontic and surgical treatment, intentional replantation, extraction, and pulp revascularization, are used according to the morphology of the involved tooth and severity of infection (19-21). The present study aimed to report a series of cases highlighting variations in DI treatment.

Case report

Ethics approval. The present study was approved by the Ethics Committee of Liaocheng People's Hospital (Shandong, China; approval no. LC2020146). The treatment procedures, risks and benefits were informed to the patient and each patient signed written informed consent for publication of their data/images.

Case series. Of five cases with DI, one was CDI (type I), two were CDI (type II) and two were RDI (type II). The inclusion criteria were as follows: Root canal treatment RCT was performed in treating CDI (type I) invagination removal combined with RCT for CDI (type II) with pulpitis and periapical lesion; conventional RCT with intentional replantation was used for the treatment of RDI; periapical surgery or intentional replantation was used for the cases with pulpitis and periapical lesion, which were not cured after RCT; intentional replantation combining with RCT, seal the invagination or root resection and back filling for RDI.

Case 1. A 40-year-old female patient sought treatment in the Department of Endodontics of Liaocheng People's Hospital (Liaocheng, China) in March 2019 for slight sensitivity to palpation and recurrent sinus on the upper left anterior region. The patient reported swelling history in the upper lip from early February 2019. Intraoral examination revealed a small crown on tooth 22, a palatal groove and a DI with normal periodontal attachment on the distal gingival margin; no caries or color alteration was observed (Fig. 1A-C). Thermal and electrical pulp testing revealed no pulp vitality. Periapical radiography revealed a well-circumscribed radiolucent area at the apex of tooth 22 (Fig. 1F). CBCT (KaVo Dental) scans were used to reveal the image of the tooth with the parameters as follows: Patient position, upright; tube current, 8 mA; focus, 0.5 mm; grayscale, 14 bt; and scan time, 20 sec. CBCT scan demonstrated that the invagination was limited within the amelocemental junction and the root was not involved (Fig. 1D and E). The patient was diagnosed with CDI (type I), necrotic pulp and chronic apical periodontitis. As the invagination was limited within the amelocemental junction and the root was not involved, conventional RCT was performed (Fig. 1G). The 6-month follow-up showed the tooth was asymptomatic and the radiolucent area was decreased in radiograph examination (Fig. 1H).

Case 2. A 21-year-old female patient, visiting the Department of Endodontics of Liaocheng People's Hospital in June 2021, complained of pus discharge from the upper right anterior region for 6 months. Intraoral examination revealed a sinus with a red and swollen fistula at the corresponding alveolar mucosa of the periapical region of tooth 12, which had an unusually large crown (Fig. 2A and B). Periapical radiography revealed an abnormal root canal and a well-circumscribed radiolucent area at the apex of tooth 12, suggesting a periapical lesion; probing with a gutta percha point under X-ray demonstrated the fistula derived from the periapical pathological lesion of the tooth 12 (Fig. 2C). CBCT scan indicated an identical tooth-like structure extending beyond the cementoenamel junction and reaching the pulpal space (Fig. 2D-G). The patient was diagnosed with CDI (type II) and chronic apical periodontitis in tooth 12. As the invagination reached the canal and the periapical tissue was affected, root canal treatment was performed; the invaginated tissue was carefully removed using an ultrasonic tip (model E3D; Guilin Woodpecker Medical Instrument Co., Ltd.) under a dental operating microscope (Carl Zeiss GmbH) (Fig. 2H-J); a 3-5 mm apical barrier was created with iRoot BP Plus root repair material (Innovative BioCeramix, Inc.); the pulp space was filled with a gutta-percha (VDW Dental) using the continuous wave of condensation technique (22) and then final composite restoration was placed (Fig. 2K and L). After 6 months, the sinus disappeared and bone healing was observed at the periapical region of tooth 12 by periapical radiography (Fig. 2M).

Case 3. A 20-year-old female patient sought endodontic treatment in the Department of Endodontics of Liaocheng People's Hospital in December 2021 for the right upper lateral incisor. The patient had undergone initial endodontic treatment on the incisor 5 years previously; after one year, the patient underwent root canal retreatment to the main and invaginated canal of the tooth due to residual pulpitis and DI (Fig. 3A-I). Here, the patient complained of recurrent mild pain, tenderness to biting and touching mucosa near tooth 12 for 3 weeks. Swelling in the infraorbital region was also reported ~1 month previously. Intraoral examination revealed sinus tract in the alveolar mucosa, proximal to the apical area of the tooth 12; there was no discomfort following percussion, but mild sensitivity to palpation. The radiograph showed that the main and the invaginated canal were filled but there was an unclear view of the canal space and variation in the distal side; in addition, there was a well-circumscribed radiolucent area at the apex of the tooth (Fig. 3J). CBCT indicated an identical tooth-like structure in the root area close to the cementoenamel junction (Fig. 3K and L). The diagnosis was CDI (type II) and chronic apical periodontitis. As the invagination reached the canal and periapical tissue was affected due to the unfilled main canal, an ultrasonic tip (E3D) was used to remove the previous root filling material and invaginated tissue under the dental operating microscope (Fig. 3M). iRoot BP was used to make an apical barrier, and the rest of canal was restored with gutta-percha; two glass fiber-reinforced posts (Nordic Glasix) were then placed into the root and the access cavity was sealed with resin composite restoration (Fig. 3N and O). When followed up after 6 and 12 months, the patient was asymptomatic and radiograph examination showed that the previous radiolucent area was decreased (Fig. 3P and Q).

Case 4. A 31-year-old female patient presented to the Department of Endodontics of Liaocheng People's Hospital in November 2020 with constant mild pain and tenderness to biting and touching mucosa near tooth 12 for 1 month. From December 2019, the patient underwent root canal treatment on

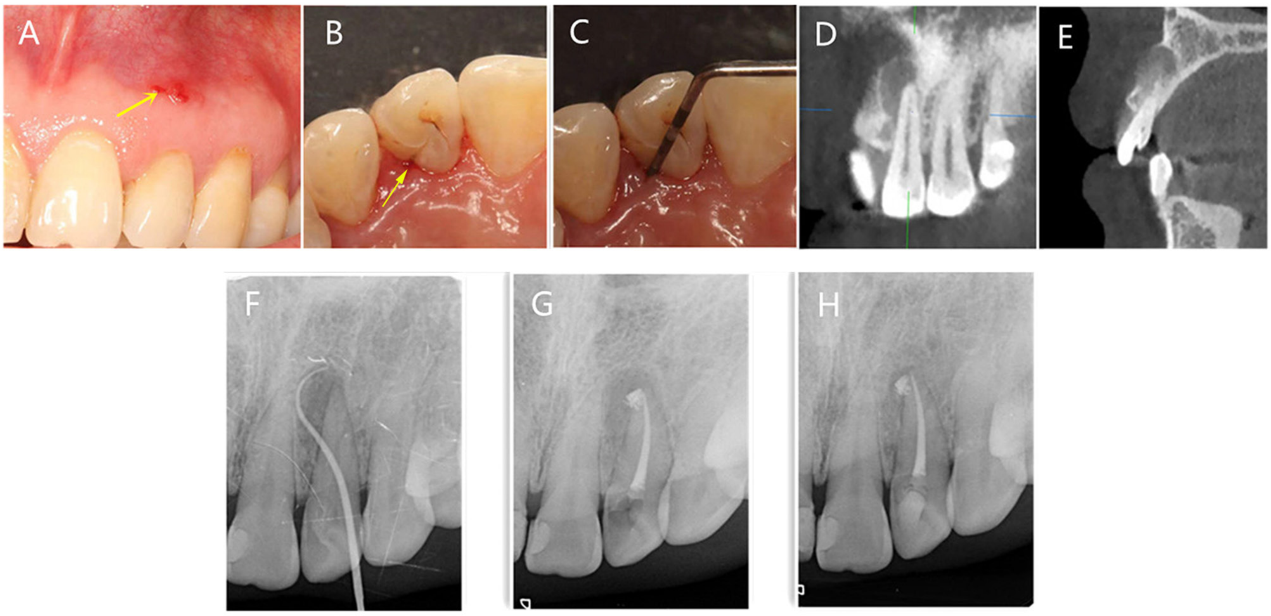

Figure 1. Case 1. (A) Sinus tract on the upper left anterior region (arrow). (B) Palatal view showing palatogingival groove (yellow arrow). (C) Normal periodontal attachment with 2 mm probing depth. (D) CBCT scan of normal root canal in coronal view. (E) Sagittal CBCT revealed the invagination was limited within the confines of the crown not extending beyond the amelocemental junction. (F) Preoperative radiograph showed periapical radiolucency and gutta-percha cone tracing to the apex. (G) Postoperative radiograph showed the root canal was completely filled. (H) Radiographical imaging at 6-month follow-up demonstrated advanced healing and periapical repair. CBCT, cone beam computed tomography.

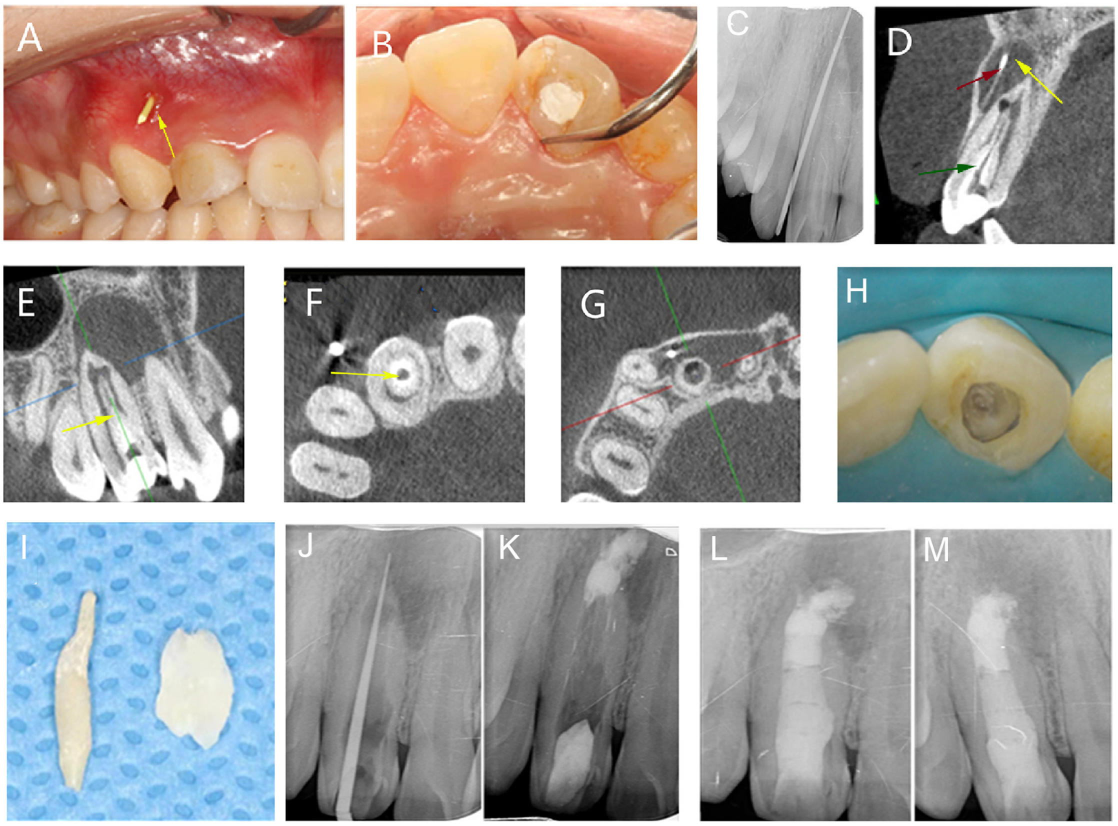

Figure 2. Case 2. (A) Sinus (yellow arrow) with a red and swollen fistula at the corresponding alveolar mucosa of the periapical region of tooth 12. Clinical crown was larger than the contralateral tooth. (B) Normal periodontal tissue and temporary sealing material in dental pulp cavity. (C) Preoperative radiography revealed periapical radiolucency and gutta-percha cone tracing to the apex. (D) Sagittal CBCT revealed periapical radiolucency (yellow arrow), gutta-percha cone tracing to the apex (red arrow) and invagination lined with enamel (green arrow). (E) Coronal CBCT revealed invagination (yellow arrow) extending beyond the cementoenamel junction reaching the pulpal space. (F) Axial CBCT section from the cervical one-third of the DI (arrow). (G) Axial CBCT section from the apical one-third of the DI. (H) Access cavity including both true root canal and the invagination. (I) Removed invaginated tissue. (J) Periapical radiography revealed invagination tissue was completely cleaned, and the working length was determined through gutta-percha cone tracing. (K) Radiographical confirmation of iRoot BP apical barrier placement. (L) Postoperative radiography demonstrated root canal was completely filled. (M) Radiographical imaging at the 6-month follow-up revealed advanced healing and periapical repair. CBCT, cone beam computed tomography; DI, dens invaginatus.

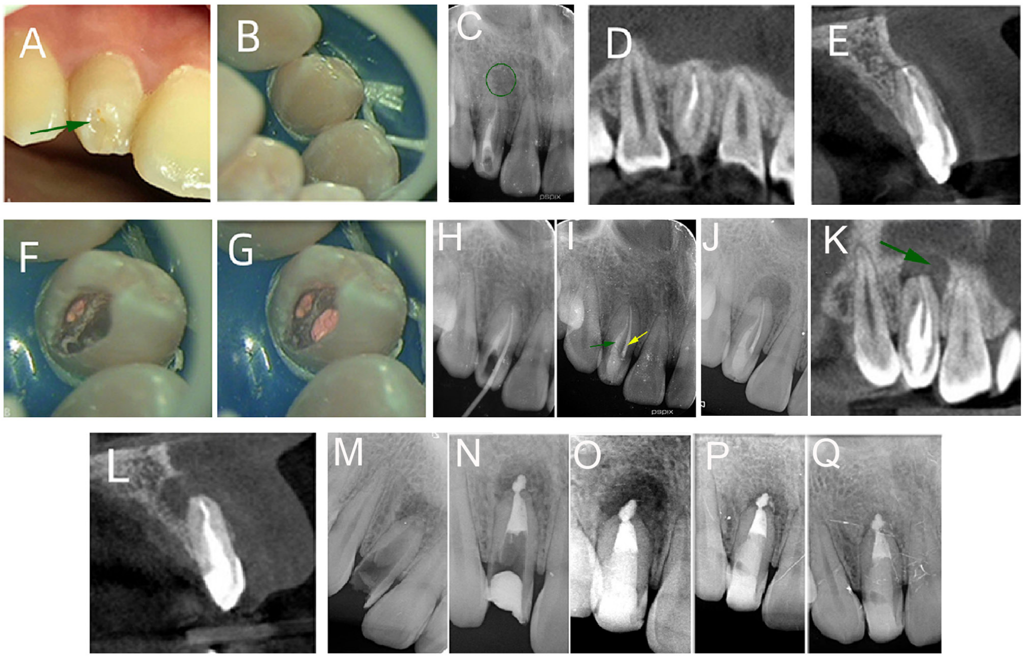

Figure 3. Case 3. (A) Cone-shaped tooth with foramen coecum on labial surface (arrow). (B) Palatal clinical image of composite resin restoration. (C) Preoperative radiograph revealed previous endodontic treatment with periapical radiolucency (circle) and DI in the mesial surface. (D) Coronal CBCT scan demonstrated invagination in the mesial. (E) Sagittal CBCT scan confirmed invagination. (F) Access cavity displayed filled root canal and the missed invagination. (G) Access cavity displayed filled root canals. Periapical radiography for (H) working length determination in invagination canal and (I) complete filling in main root canal (yellow arrow) and invagination (green arrow). (J) Periapical radiography demonstrated previous inadequate endodontic treatment and periapical radiolucency. (K) Coronal CBCT scan showing inadequate filling in invagination and a large apical osteolytic zone (green arrow). (L) Sagittal CBCT scan confirmed the periapical radiolucency. (M) Periapical radiography demonstrated the complete main root after removing invaginated tissue. (N) Radiographical confirmation of iRoot BP apical barrier placement. (O) Postoperative radiography demonstrated complete root canal filling. Radiographical imaging at (P) 6-month follow-up revealed advanced healing and periapical repair and (Q) 12-month follow-up revealed almost normal periapical tissue. CBCT, cone beam computed tomography.

the complaint tooth. Following intraoral examination, a sinus tract was observed in the alveolar mucosa, proximal to the apical area of tooth 12 (Fig. 4A); a palatal groove with ~5 mm periodontal loss at the groove site was observed (Fig. 4B). Radiography showed an extra canal beside the main one, a large periapical radiolucent lesion and bone resorption related to the main root (Fig. 4C). The CBCT scan showed invagination extending from the crown into the apex of the root (pseudo canal), with no evident communication with the main canal (Fig. 4D-G). The patient was diagnosed with RDI (type II) and chronic apical periodontitis. The aberrant anatomical structure hampered adequate sterilization and obturation and conventional root canal treatment could not eliminate the infected pulp tissue completely and seal the pseudo canal tightly. The aim of the treatment for RDI is eradicating the invagination and apical periodontitis; therefore, the patient underwent conventional root canal treatment to the main root and intentional replantation. Under a dental operating microscope, apex of the extracted tooth was resected with high-speed handpiece for 3 mm and iRoot BP was placed to seal the retrograde cavity (Fig. 4H-K); the tooth was gently replanted into the socket and fixed with composite resin splint (Fig. 4L). The 3-month follow-up radiograph showed a reduction of the previous radiolucent area (Fig. 4M). A 1-year follow-up radiograph was not collected as the patient was pregnant.

Case 5. A 54-year-old male patient was referred to the Department of Endodontics of Liaocheng People's Hospital in February 2021 for continuous sensitivity to palpation on the palate side of tooth 11 for the past 3 years. The tooth had been treated repeatedly with non-surgical root canal treatment during the past 12 months and received apical surgery 6 months ago. Intraoral clinical examination revealed the tooth was filled with composite restorative resin, and a radicular groove was detected in the palatal face of the tooth extending from the cingulum to gingival sulcus, with a nearly 10 mm probing depth. Periapical radiography revealed a densely filled root canal and radiolucent area with an opaque margin surrounding the apex of tooth 11 (Fig. 5A). CBCT indicated the palatogingival groove extending from central fossa to the root apex and the apical foramen being surrounded with a large periapical radiolucent lesion (Fig. 5B and C). The patient was diagnosed with RDI (type II) and chronic apical periodontitis. The previous treatment failure was caused by the aberrant anatomical structure and the improper therapeutic strategy as conventional root canal treatment cannot clean out the infected pulp tissue thoroughly and seal the pseudo canal tightly. The patient underwent intentional replantation and surgical treatment. Main root tip (~3 mm) was resected and the root foramen was prepared by ultrasonic tips and back-filled with iRoot BP (Fig. 5D-G); the tooth was replanted into its alveolar bone and fixed by a wire and composite resin splint (Fig. 5H). At 6-month follow-up, the patient was asymptomatic and radiograph examination showed a reduction of the radiolucent area (Fig. 5I). At 24-month follow-up, radiograph showed that the periapical radiolucent lesion disappeared and the patient was asymptomatic (Fig. 5J-N).

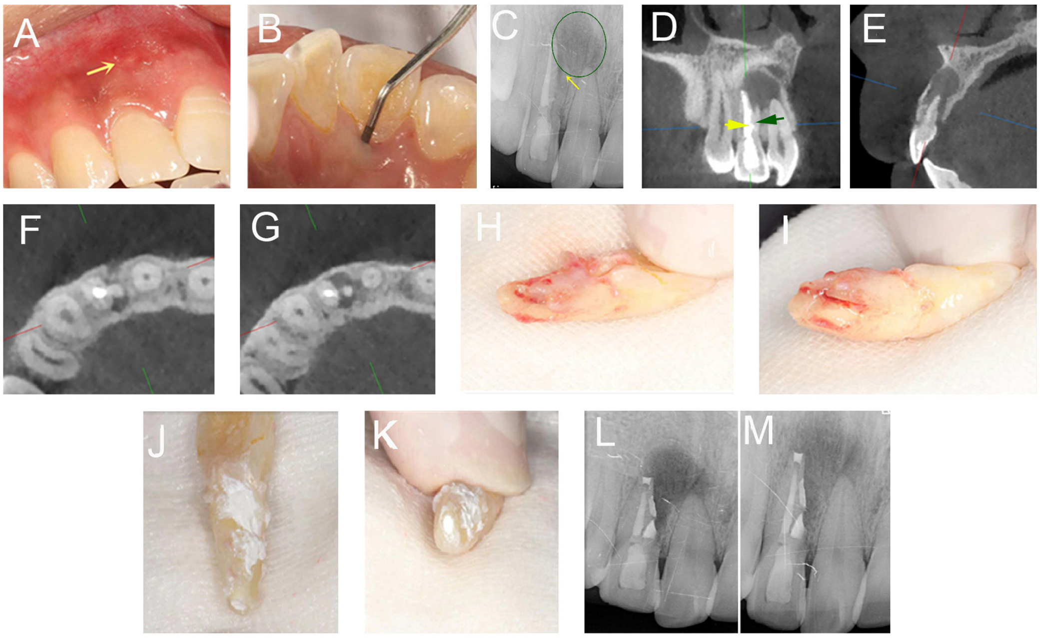

Figure 4. Case 4. (A) Sinus tract of tooth 12 (yellow arrow). (B) Palatogingival groove with a narrow 8 mm periodontal pocket and composite resin restoration. (C) Preoperative radiograph revealed the previous endodontic treatment, the invagination (yellow arrow) and periapical radiolucency (circle). (D) Coronal CBCT demonstrated main root canal (yellow arrow) and invagination (green arrow). (E) Sagittal CBCT confirmed the missed invagination and periapical radiolucency. Axial CBCT view of the (F) middle and (G) axial one-third showed no connection between the root canal and the invagination. (H) Cingulum and (I) mesial surface of the extracted tooth with a palatogingival groove extending from cingulum to the root apex. (J) Palatogingival groove including (K) the root-end cavity was filled with bioceramics iRoot BP. (L) Postoperative radiograph following replantation. (M) Radiograph taken at 3-month follow-up indicated advanced healing and periapical repair. CBCT, cone beam computed tomography.

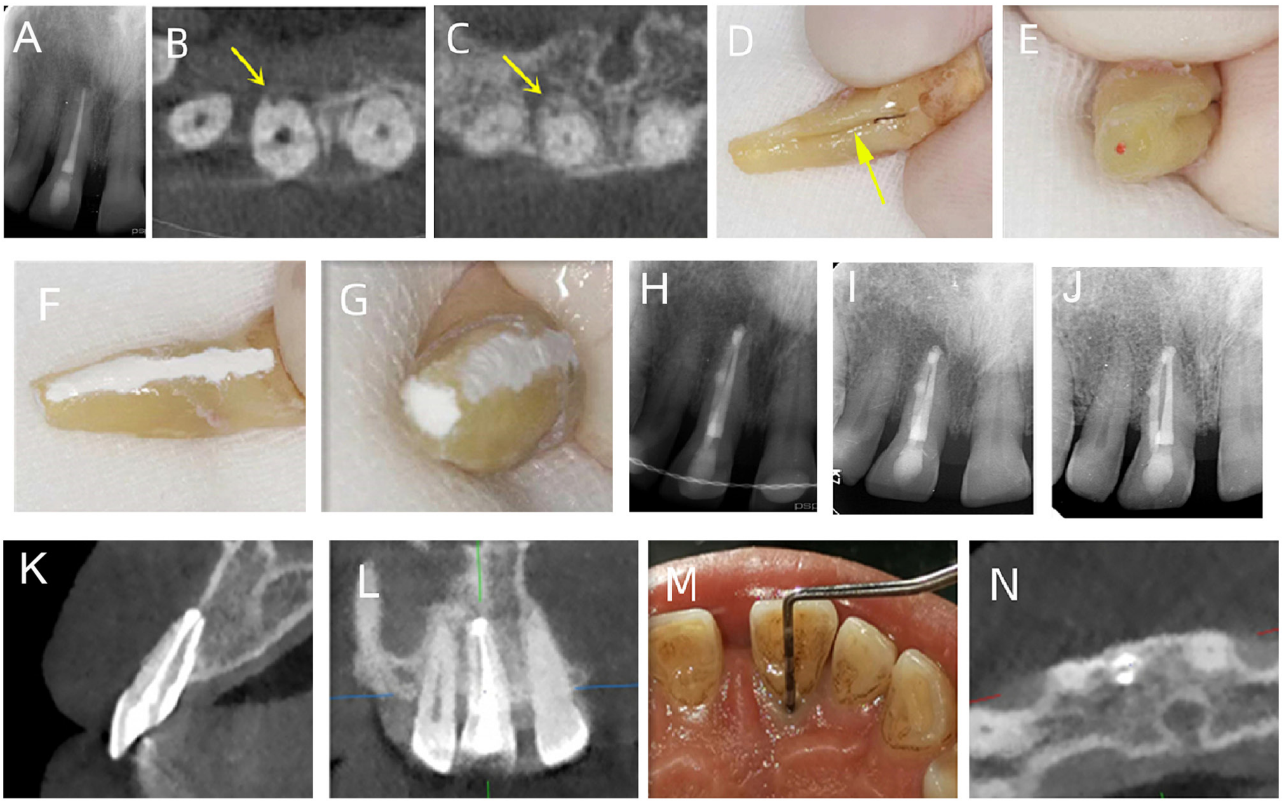

Figure 5. Case 5. (A) Preoperative radiograph revealed previous endodontic treatment with apicetomy and periapical radiolucency. (B) Axial CBCT imaging revealed a palatogingival groove in the (B) cervical and (C) apical one-third view (arrow). (D) Palatogingival groove (yellow arrow) extending from the cingulum to the root apex. (E) Root tip (~3 mm) was resected. (F) Palatogingival groove was removed and filled with bioceramics iRoot BP. (G) Root end was backfilled with iRoot BP. (H) Tooth was replanted into the alveolar bone and splinted with orthodontic ligature. (I) Postoperative radiograph taken at the 6-month follow-up indicated advanced healing and periapical repair. (J) Postoperative radiograph at the 24-month follow-up indicated healed periapical tissue. (K) Sagittal and (L) coronal CBCT imaging taken at the 24-month follow-up. (M) Palatal view indicated normal periodontal tissue with no pocket at the 24-month follow-up. (N) Axial CBCT imaging taken at the 24-month follow-up. CBCT, cone beam computed tomography.

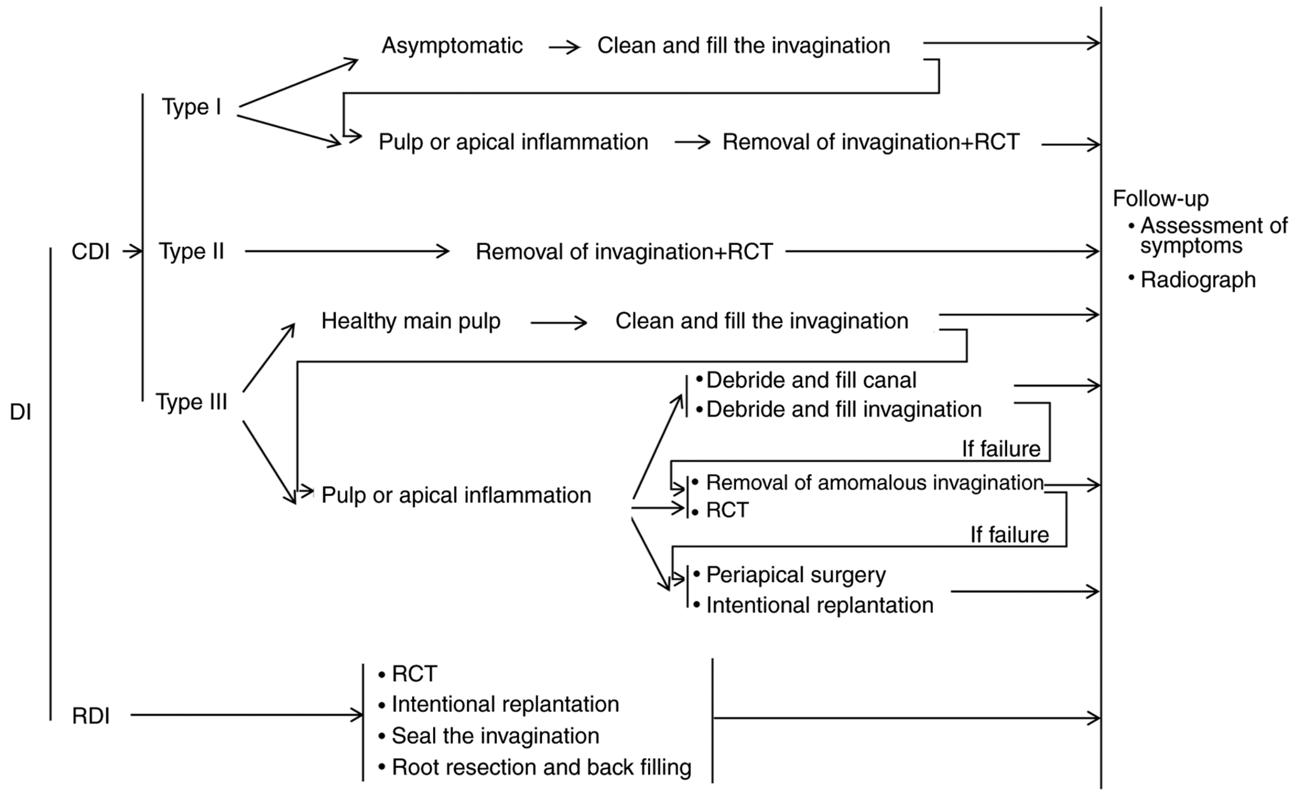

Figure 6. DI therapeutic strategies and procedures according to the classification of DI in the Department of Endodontics of Liaocheng People's Hospital (Liaocheng, China). CDI, coronal dens invaginatus; RDI, radicular dens invaginatus; RCT, root canal treatment.

Discussion

The clinical manifestation of DI can be a palatal pit or groove, a barrel- or cone-shaped tooth, dilated crown or a microdontic tooth (5). The deep pit or groove of abnormal crown morphology, where saliva, food remnants and bacteria are trapped, make DI teeth susceptible to caries (23,24). If the enamel lining the surface of the invagination is naturally absent or destroyed by caries, bacteria and their products can diffuse to the pulp, leading to pulpitis and periapical periodontitis (13,25). Therefore, early and correct diagnosis of DI is especially important to implement appropriate prevention or treatment strategies for DI.

The complexity of DI is associated with its anatomy; understanding the accurate anatomy is key to diagnose and treat DI. Conventional radiological examinations, such as periapical and panoramic radiograph, are routinely used for early diagnosis of DI. However, these imaging techniques only show 2-D information and cannot be used to depict the 3-D structure of the malformation; misdiagnosis of the anomaly may lead to inappropriate treatment, as in case 5. At present, 3-D imaging techniques in endodontics, such as spiral CT and CBCT, are widely used in diagnosing and managing DI (26,27). Due to its lower radiation dosage, high efficiency and high resolution and accuracy, CBCT is a preferable complementary examination to depict complicated root canals of both CDI and RDI teeth, especially for type II and type III (28). In case 4, CBCT revealed a remnant root canal in the affected tooth, which was not seen by periapical radiograph, leading to misdiagnosis and treatment failure; many case reports reveal the superiority of CBCT in detecting canal variations in DI (29,30). A previous case report demonstrated that CBCT shows the accurate location of the invagination and reveals no communication between the invagination and the main root canal (31); in the aforementioned study, according to the CBCT manifestation, conservative management, endodontic treatment to invagination and untreated root canal with a vital pulp was performed to allow the tooth to develop.

There are numerous reports about DI treatment (32-35) and several comprehensive treatments, such as combining surgical and conservative endodontic management, have been suggested (36); however, there is no authoritative treatment standard being reported. Treatment of DI depends on the type of invagination, complexity of root canal anatomy, the pulp activity and the morphology of the apex. Practitioners should select an appropriate therapeutic method or design a regimen combining several methods according to the individual condition. For CDI (type I) without pulp infection, invagination sealing or filling is the first choice (32); however, Schmitz *et al* (33) reported that even without pulp infection, CDI (type I) should be treated with root canal. For CDI with infected pulp or periapical inflammation but without periodontal bone change, such as in case 1, conventional root canal treatment is necessary. For CDI (type II) with infected pulp or a periapical lesion, root canal treatment is necessary and thoroughly eliminating infection in canal is key. Nasrabadi *et al* (34) reported a type II DI treated with root canal yielded favorable prognosis. There is a controversy about whether the invaginated canal should be removed: George *et al* (37) reported a type II case in which, to avoid the decrease in root strength, the main and the invaginated canal were filled separately without removing the invagination. Subay and Kayatas (35) reported an immature type II DI treated with apexification and filling both the root canal and the invaginated canal; however, no sign of apex development appeared, which was attributed to residual debris in invagination affected cleaning and filling of the main root canal, resulting in poor prognosis; therefore, removing the invagination thoroughly to achieve sufficient canal cleaning is suggested, and this strategy has become feasible through the application of microscopic and ultrasonic techniques (38,39). In cases 2 and 3, invaginations were removed completely with ultrasonic techniques under a microscope, which facilitated thorough debridement of the main canal. Apical barrier technique provided complete apical sealing, resulting in good prognosis. The root canal system of CDI (type III) is complex, so correct assessment of the main pulp condition is key for treatment. If the main pulp is healthy, to maintain the main canal pulp vitality, only cleaning and filling the invaginated canal is suggested; Heydari and Rahmani reported a case in which only the invaginated canal was cleaned and filled; the periapical lesion resolved completely and the tooth remained vital (40). If the main canal pulp is infected, as reported by Agrawal *et al* (41), separate debriding and filling both of the main and invaginated canal are needed. Other endodontists suggest removing the extremely large anomalous invagination with ultrasonic instruments and fusing the main canal and invaginated canal as one space to benefit sterilization and sealing completely; Martins *et al* (42) reported a case of CDI (type III) in which dens were removed regardless of whether pulp was infected and the main canal was debrided and filled. If conservative treatment fails or the invaginated canal cannot be cleaned and filled by traditional methods, periapical surgery or intentional replantation is recommended as an alternative to extraction (20,43). Oliveira *et al* (44) reported complex combined endodontic treatment of a type III DI in a maxillary lateral incisor with extensive periapical lesion affecting the buccal and palatine cortical bone treated with endodontic and surgical treatment, including bioceramic sealer, mineral trioxide aggregate (MTA) repair high plasticity and bone graft. A retrospective study of ten cases of CDI (type III) with apical periodontitis revealed survival rate of intentional replantation was 80% (45). In RDI, the lingual groove is a silent nidus for plaque formation, contributes to coalescence between pulp and periodontal ligament and leads to complicated combined periodontal-endodontic lesions. Extraction has been the final resort in the past. Successful treatment for RDI depends on both effective periodontal treatment and resolution of associated localized periodontal defect, so combined endodontic and periodontal treatment is suggested. Periapical surgery combined with root amputation and sealing with MTA and guided bone regeneration are suggested to restore the original ridge volume in teeth without deep periodontal pockets (46). Intentional replantation is recommended because of its advantage in directly visualizing length, depth, location of palatal grooves and debridement infection thoroughly. Garrido *et al* (47) described a case of a maxillary lateral incisor with deep palatogingival groove extending to the root apex and severe periodontal destruction treated with endodontic therapy and intentional replantation following restoration with a self-etching flowable composite, resulting in periodontal healing and notable healing of the periradicular radiolucency. Tan *et al* (48) successfully treated a radicular groove using a combination of endodontic therapy, intentional replantation and root resection. For RDI cases with single-root, intentional replantation with a 2-segment restoration method (dividing the groove cavity into two parts at the cementoenamel junction, then filling coronal part with flowable composite and apical part with iRoot BP) is an optimal treatment to eliminate the infection completely and promote periapical tissue regeneration effectively (49). In cases 4 and 5, combined endodontic therapy, intentional replantation and root resection with iRoot BP filling both the palatal groove and the root apex was adopted, leading to good prognosis.

Strategy for DI treatment is shown in Fig. 6. The indicators for efficacy of DI treatment in the Department of Endodontics of Liaocheng People's Hospital include: i) No conscious symptoms, such as pain and swelling; ii) no discomfort during chewing; iii) normal periapical mucosal soft tissue without redness or abscess; iv) fistula disappearance without tenderness and percussion; v) healthy gingiva without redness, swelling or pus discharge and vi) radiographical findings of intact tooth, tightly filled canal and periapical lesions reduced or missed. In the present cases, lack of symptoms and the aforementioned radiograph manifestations were considered indicators for the efficacy of DI treatment, as previously reported (16,30,50,51). The complications of DI management methods are mainly secondary pulpitis, periapical periodontitis and periodontal disease. When complications occur, symptoms should be treated (for example, RCT for pulpitis and periapical periodontitis). If a complication means that the tooth cannot be saved, extraction along with a restoration of the missing tooth is necessary.

Numerous types of congenital malformation can be screened at an early stage; for example, cleft lip and palate can be screened by genetic techniques or ultrasound inspection in the embryonic development period (52,53). Considering that DI is not a lethal or severely teratogenic congenital malformation and is hard to screen during its development, clinical therapy is more important than early detection or prevention.

CBCT is an essential tool in assessing DI and guiding treatment, especially in CDI (types II and III) and RDI cases. Treatment should be based on the type of invagination, complexity of root canal anatomy, level of pulp involvement, morphology of apex and the periodontal status.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

RZ was responsible for conceptualization. CW and RZ conceived the study and drafted the manuscript. DW and PL performed treatments. RZ, LS and ZM collected and analyzed the data. CW and LS supervised the study. CW, DW, PL, ZM and RZ reviewed and edited the manuscript. ZM and RZ confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

The present report was approved by the Ethics Committee of Liaocheng People's Hospital (Shandong, China; approval no. LC2020146).

Patient consent for publication

All patients involved in the present study provided written informed consent for publication of their data and images.

Competing interests

The authors declare that they have no competing interests.

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