REVIEW ARTICLE

Dens Invaginatus: Clinical Implications and Antimicrobial Endodontic Treatment Considerations

José F. Siqueira, Jr., PhD,[*†‡] Isabela N. Rôças, PhD,[*†‡] Sandra R. Hernández, MSc,[*‡§] Karen Brisson-Suárez, DDS,[*‡‖] Alessandra C. Baasch, DDS,[*‡‖] Alejandro R. Pérez, PhD,[†‡¶] and Flávio R. F. Alves, PhD[*†]

ABSTRACT

Dens invaginatus or dens in dente is a developmental dental anomaly resulting from an invagination of the enamel organ into the dental papilla during odontogenesis. Radiographically, it is usually seen as a radiolucent invagination surrounded by a radiopaque area (enamel) limited to the tooth crown or extending into the root. Because the invagination is opened to the oral cavity, it can retain saliva, food remnants, and bacteria. In conditions where the enamel lining of the invagination is naturally absent or lost because of caries, bacterial cells and products can diffuse from the invagination through the dentin tubules to reach the pulp and cause disease. Management of teeth with dens invaginatus includes preventive sealing or filling of the invagination, or if the pulp is affected, therapeutic options include vital pulp therapy, nonsurgical root canal treatment, apexification or regenerative endodontic procedures, periradicular surgery, intentional replantation, or extraction. It is recommended that the invagination be always approached, regardless of the type of dens invaginatus. The root canal should be treated whenever the pulp is irreversibly inflamed or necrotic. Endodontic management of teeth with dens invaginatus is often tricky because of its anatomic complexity, and special and customized strategies should be devised. This review discusses the endodontic implications of this anomaly and the current treatment recommendations based on anatomic, pathological, and technologic considerations. *(J Endod 2022;48:161–170.)*

KEY WORDS

Apical periodontitis; dens invaginatus; root canal infection; root canal treatment

SIGNIFICANCE

The present narrative updated and expanded the discussion about the endodontic implications of dens invaginatus as well as the current treatment recommendations based on anatomic considerations and new technologies.

Dens invaginatus or dens in dente is a developmental malformation that radiographically looks like one tooth inside another one, which has inspired the terminologies used to define this condition[1]. Although its etiology is controversial and several theories try to explain its formation[1,2], it is widely accepted that dens invaginatus may result from an invagination of the enamel organ into the dental papilla during odontogenesis, before calcification occurs.[1] External factors such as trauma or infection may also influence its development[3,4]. The occurrence of dens invaginatus may be related to genetic factors[3,5], but research in this field is still limited.

Dens invaginatus is among the most prevalent developmental tooth anomalies. Its prevalence in permanent teeth varies from less than 1% to 10%, depending on the population studied[3]. Genetic factors related to ethnicity may be the reason for differences in prevalence in diverse geographical areas. Bilateral occurrence affecting contralateral teeth is not uncommon[6,7], representing 43% of the cases[8]. The maxillary lateral incisor is the most affected tooth, followed by the maxillary central incisor, canines, and premolars[1,4,9]. The occurrence of dens invaginatus in molars is rare.[10] Primary teeth can also exhibit this anomaly[11].

Because dens invaginatus is frequently associated with pulp and periradicular diseases, endodontic management is often required to save and treat the affected tooth, but it is frequently challenging because of the variable and aberrant anatomy[3,12–14]. The purpose of this narrative review is to update and expand the discussion about the endodontic implications of dens invaginatus as well as the treatment recommendations based on anatomic considerations and new technologies.

From the *Postgraduate Program in Dentistry, University of Grande Rio (UNIGRANRIO), Rio de Janeiro, RJ, Brazil; †Department of Dental Research, Faculty of Dentistry, Iguaçu University (UNIG), Nova Iguaçu, RJ, Brazil; ‡Endochat Research Group, Rio de Janeiro, RJ, Brazil; §Department of Endodontics, Francisco Marroquín University, Guatemala City, Guatemala; ‖Department of Endodontics, Santa María University, Caracas, Venezuela; and ¶Department of Endodontics, University Rey Juan Carlos, Madrid, Spain

Address requests for reprints to Dr Flávio R. F. Alves, Rua Professor José de Souza Herdy, 1160, Duque de Caxias, RJ, Brazil 25071-202.
E-mail address: flavioferreiraalves@gmail.com
0099-2399/$ - see front matter

https://doi.org/10.1016/j.joen.2021.11.014

CLASSIFICATION

There have been some attempts to categorize the different manifestations of dens invaginatus. The first one was proposed by Hallett[15] in 1953 and included 4 types mostly based on the invagination morphology. However, the most widely used classification was described by Oehlers[13,14] in 1957, which included 3 types based on the vertical extension of the invagination (Fig. 1). Oehlers' type I consists of an invagination that is limited to the tooth's crown and does not penetrate the root. In type II dens invaginatus, the invagination extends through the root and ends in a blind sac without communication with the periodontium. In type III, the invagination goes all the way from the crown opening up to the periodontal ligament laterally (subtype IIIa) or apically (subtype IIIb), forming an additional lateral or apical foramen, respectively.

Oehlers' classification is simple and helpful to guide treatment planning. It distinguishes between complete (type III) and incomplete invagination (types I and II), which is of great relevance because the management of each one can be very different. A limitation of this classification is its bi-dimensional nature, especially nowadays when advanced three-dimensional imaging examination has become widely available and can play an important role in improving the management of teeth with complicated root anatomy[16,17].

A radicular variety of dens invaginatus has been reported[18], with 2 types being identified. One is characterized by a cementum-lined invagination in the root; its morphology and clinical characteristics are entirely different from other forms of dens invaginatus. This is currently referred to as palatogingival groove or radicular groove. The second type is characterized by an enamel-lined invagination involving only the root, with only a few cases reported in the literature[19]. The coronal type of dens invaginatus is by far the most common variety and as such is the subject of this review.

DIAGNOSIS

Unless the patient presents with pain and/or swelling associated with the involved tooth, dens invaginatus is commonly diagnosed as an incidental radiographic finding. In addition, although some teeth with dens invaginatus may have a normal appearance, most cases exhibit an atypical crown, with a conical, peg-shaped, barrel-shaped, or dilated morphology, or have a bifid exaggerated cingulum. Consequently, it is recommended that the clinician performs a radiographic examination of teeth with an abnormal crown anatomy to check for the possibility of dens invaginatus or other anomalies[19].

Dens invaginatus can also be a diagnostic problem and may be suspected when the patient presents symptoms of pulpitis in a tooth without a history of trauma or caries. Ricucci et al[10] reported on a case of complicated diagnosis in which the cause of pulp inflammation and necrosis was dens invaginatus that was only detected after extraction and histopathological analysis. In teeth with dens invaginatus, the results of pulp sensitivity tests depend on the dental pulp conditions; the invagination does not respond to pulp sensitivity tests because it does not contain a vital innervated tissue. Sometimes the tooth with dens invaginatus can present an apical periodontitis lesion but still responds to the sensitivity tests. This indicates that infection is established in the invagination that communicates with the periradicular tissues (Oehlers' type III) but has not affected the pulp significantly.

Radiographic examination is essential to a correct diagnosis of dens invaginatus. The invagination usually appears as a radiolucent pocket lined by radiopaque borders (enamel) and is either confined to the crown or extended into the root. Communication between the invagination and the apical or lateral periodontal ligament may be evident and associated with a periapical or lateral bone radiolucency[20].

Nevertheless, conventional periapical radiographs are usually of limited diagnostic information because they show only a bi-dimensional view of the very complex anatomy of dens invaginatus. In cases where dens invaginatus is identified or suspected, cone-beam computed tomography (CBCT) has become an invaluable tool to define the invagination type, establish its three-dimensional spatial relationship with the tooth anatomy and the pulp space, and plan the best treatment strategy (Fig. 2)[17,21].

In CBCT axial sections, the invagination is often seen as a canal lined by a radiopaque enamel circle (Fig. 3). It can exhibit several different configurations, and the presentation

FIGURE 1 – Oehlers' classification of dens invaginatus. (*A*) Type I. (*B*) Type II (courtesy Inês Inojosa). (*C*) Type III.

FIGURE 2 – CBCT images of teeth with dens invaginatus types II (*A*, courtesy Marcelo Sendra) and III (*B*, courtesy Patricia Ferrari).

can vary even among the different cross sections of the same tooth from the coronal to the apical third of the root. For instance, the invagination may be located centrally in the root, and the true canal can be displaced in a buccal or palatal/lingual direction, often assuming a C-shaped morphology (Fig. 4). Other times the invagination appears as another canal in the root (Fig. 4). In many teeth with types I and II, the true root canal assumes a rather normal morphology in the root portion apically to the invagination.

Combined with clinical examination, CBCT is of great value to a differential diagnosis between dens invaginatus and palatal radicular groove. Both entities may exhibit grooves deriving from the cingulum[22]. However, the presence of a hyperdense image inside the tooth (enamel lining of the invagination) in CBCT slices is highly suggestive of dens invaginatus.

INVAGINATION OR PSEUDOCANAL

The main feature of dens invaginatus is the occurrence of an invagination that is opened to the oral cavity. The entrance of the invagination on the crown may appear like a pit, groove, or deep foramen cecum on the palatal or occlusal surface of the tooth, in many cases affected by caries[19,23]. On rare occasions, the opening can be found in other areas such as the buccal face of the tooth crown (Fig. 5).

If narrow and small, the invagination opening can be difficult to detect during inspection, mainly when bacterial plaque or food accumulates on its opening, preventing visualization. The operating microscope and stains may be valuable tools for the detection of the dens invaginatus opening.

The invagination is like a pseudocanal with the walls lined by enamel. The enamel lining may not be uniform, exhibiting interruptions and pits, or it can be lost as a result of caries, resulting in a direct communication of dentin or even the pulp with the lumen of the pseudocanal[4,24]. Before tooth eruption, the invagination is filled by remnants of the dental papilla or the enamel epithelium[25]. After eruption, the invagination can be filled with saliva, food remnants, and bacteria. Bacterial colonization and accumulation in the invagination, with or without caries formation, represent a serious risk for adverse pulp reactions, including inflammation, necrosis, and infection.

GENERAL TREATMENT CONSIDERATIONS

The management of teeth with dens invaginatus varies according to the invagination extent (Oehlers' type), pulp and periradicular status, and the stage of root development. Therapy includes preventive sealing/filling of the invagination, nonsurgical root canal treatment, apexification or regenerative endodontic procedures, periradicular surgery, intentional replantation, or extraction. In virtually all cases of dens invaginatus, it is recommended to approach the invagination, regardless of the pulp condition, either to prevent pulp pathology or to help treat a tooth with necrotic pulp with or without apical periodontitis.

Early detection of dens invaginatus prevents future complications. If this condition is suspected or confirmed by imaging examination, inspection with the aid of a stain such as methylene blue and magnification by an operating microscope can facilitate the detection of the coronal opening of the invagination. In general, if the pulp sensitivity tests and the clinical and radiographic

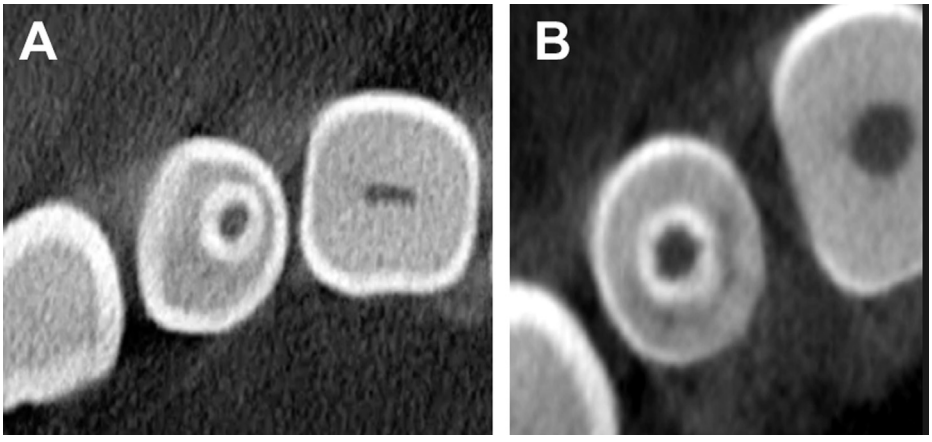

FIGURE 3 – Axial CBCT sections showing the invagination lined by enamel (*A*, courtesy Marcelo Sendra; *B*, courtesy Patricia Ferrari).

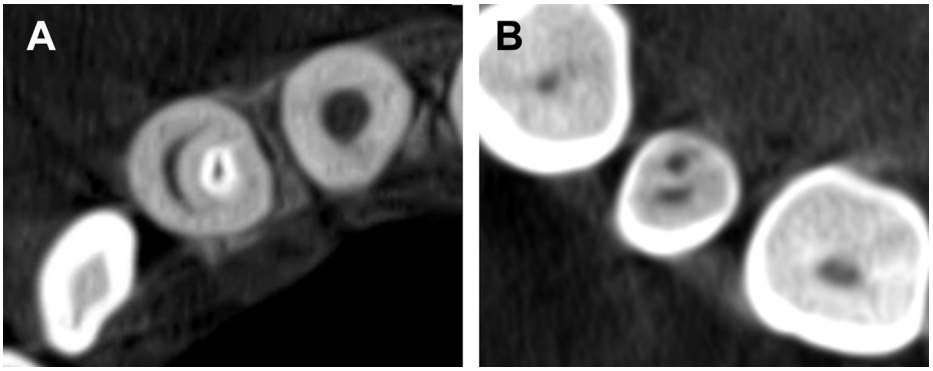

FIGURE 4 – Axial CBCT sections. (*A*) The true root canal is displaced by the invagination and assumes a C-shaped morphology (courtesy Jorge Alberdi). (*B*) The invagination appears as another canal. (courtesy Florencia Cires).

conditions indicate that the pulp is vital and not inflamed, the recommendation is just to seal the entrance of the invagination or perform a minimal preparation with a small bur and fill it to prevent saliva penetration and bacterial colonization.

Every single case of dens invaginatus is different from the others, so any standardization of treatment approach is complex and may not suffice to deal with the different conditions properly. Therefore, anatomy-based planning is essential for success and requires a good imaging diagnosis. Radiographs and CBCT are essential tools to plan the access preparation and other treatment strategies. Evaluation of pulp vitality and the presence of a periradicular inflammatory lesion will guide the decision-making process for adequate management.

New technologies such as guided endodontics[26] and computer-aided dynamic navigation[27,28] may be used for planning and more accurate management of dens invaginatus. The use of a guided endodontic technique for managing maxillary lateral incisors with dens invaginatus has been reported[29].

The preparation of the access cavity is an important technical difficulty because of the location of the pulp chamber and the invagination (Fig. 6). The invagination in most cases should be included in the final access preparation shape together with the pulp chamber (Fig. 7). In some instances, the invagination may be entirely removed by using an ultrasonic instrument to facilitate root canal access[30]. There are also instances where 2 access cavities are prepared, one for the invagination and the other for the true canal[29,31]. Magnification by the operating microscope can be of great value for access preparation in teeth with dens invaginatus.

Even more challenging is to perform chemomechanical preparation of both the invagination and the true canal. Both have irregular anatomy that is difficult to clean, disinfect, and fill. In most teeth with type II and all teeth with type III, the invagination should be treated as a root canal. Rotary instrumentation, preferably using conforming (adjustable) instruments, aided by hand instruments, may be necessary to improve cleaning and shaping in many cases. However, the very complex anatomy may require supplementary disinfection steps after chemomechanical procedures, including activation of sodium hypochlorite (NaOCl) by mechanical (XP-Endo Finisher, FKG Dentaire, La Chaux-de-Fonds, Switzerland), sonic (EndoActivator, Dentsply Sirona, Tulsa, OK) or ultrasonic means and an interappointment intracanal medication[32].

FIGURE 5 – Opening of the invagination occurring on the buccal side of the crown. (courtesy Santiago Di Natale).

An intracanal medication with calcium hydroxide paste represents an effective approach to improve disinfection of the root canal system after preparation[33–36]. Adding a radiopacifier to the calcium hydroxide paste may be indicated to reveal whether the paste is reaching the irregularities of both the true canal and the invagination (Fig. 8). If the vehicle used is distilled water, saline, or camphorated paramonochlorophenol/glycerin, it is recommended to remove the paste 7–14 days after application by irrigating with NaOCl and using the master apical file or one size larger[37,38]. This is because studies showed that pretreatment with calcium hydroxide makes the organic tissue more prone to dissolution by NaOCl[39,40], not to mention the antibacterial effects of an additional NaOCl irrigation[37]. If chlorhexidine is the vehicle for calcium hydroxide, paste removal should be conducted by copious irrigation with a chlorhexidine solution.

In dens invaginatus types II and III, both the canal and the invagination should be obturated preferably with a thermoplasticized technique for better filling of the anatomic irregularities[41,42]. The invagination may alternatively be filled with mineral trioxide aggregate (MTA) or other bioceramic materials[43,44]. If not eliminated during access preparation, type I invagination can be filled with a permanent restorative material.

If the pulp is necrotic and the apex is open, apexification or a regenerative

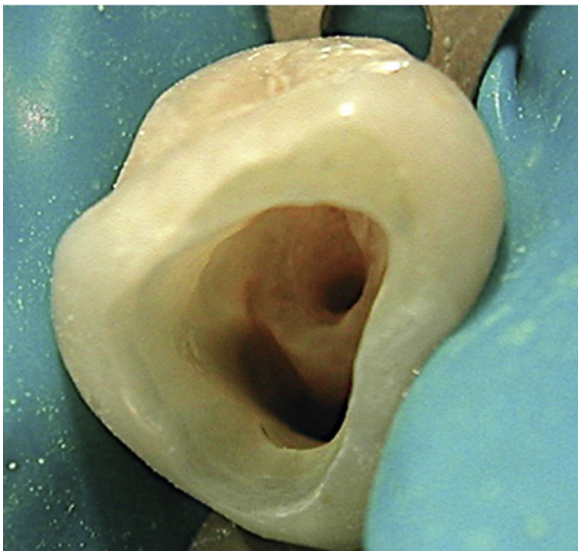

FIGURE 6 – Access cavity showing the true root canal with a C shape and the invagination. (courtesy Santiago Di Natale).

procedure is indicated to stimulate apical closure, preferably by continued root formation[45–47]. In cases where apexification is the treatment of choice, it can be done by placing an apical barrier with MTA or other bioceramic material[44,48] after at least 1 week of calcium hydroxide medication to improve disinfection. Another option is a long-term calcium hydroxide treatment until root closure is observed.

If the root is too short and/or has thin walls, regenerative endodontic procedures might be the first treatment option. The main indications involve teeth with Cvek's stages 1 to 3 of root development, ie, from less than one half of root formation to two thirds of root development with open apex[49]. This is because the regenerative procedures can result in thickening of the canal walls and/or continued root development. Immature teeth at stage 4, which show nearly completed root formation with an open apex, can be managed with either regenerative endodontics or apexification[50]. There have been reports of dens invaginatus types II and III in immature teeth treated by regenerative procedures[51,52]. According to the American Association of Endodontists, the main criteria to consider regenerative endodontic procedures as successful involve eliminating symptoms, evidence of bone healing, and increased root wall thickness and/or increased root length[53].

In cases where nonsurgical root canal treatment fails or is not even feasible, periradicular surgery using MTA (or other bioceramic material) as the root-end filling material is indicated to save the tooth and restore the periradicular health[54,55]. In type III dens invaginatus, root-end preparation and filling of the invagination should also be done. It is advisable to clean the irregularities of the root canal and the invagination with ultrasonics before placing the root-end filling. Antimicrobial photodynamic therapy has also been shown to improve disinfection of both the resected root surface and root-end cavity during apical surgery[56]. In cases of surgical failure, intentional replantation may be indicated as the last attempt to save the tooth[57].

TREATMENT RECOMMENDATIONS IN SPECIFIC CASES

Different approaches are recommended for the different conditions (Fig. 9).

Type I Dens Invaginatus

Vital Pulp

Non-inflamed pulp. If the pulp is vital and healthy, it is advisable to seal the invagination to prevent further problems. This can be done by using acid-etched fissure sealant or flowable composite resin material to seal the entrance of the invagination or to fill it (after preparing a small cavity) with resin or glass ionomer. If caries is detected in the invagination, this should be removed by using round (if necessary long-necked) burs and/or ultrasonic tips under magnification and abundant illumination. Follow-up is essential to regularly monitor the tooth for pulp health and the restoration status[58].

Inflamed pulp. If the pulp is vital but diagnosed as with irreversible pulpitis, root canal treatment is indicated. Because bacterial infection of the invagination is the most likely cause of pulp inflammation, it should be cleaned and disinfected before being filled and sealed. Ultrasonic tips can be used for this purpose. The true root canal should be

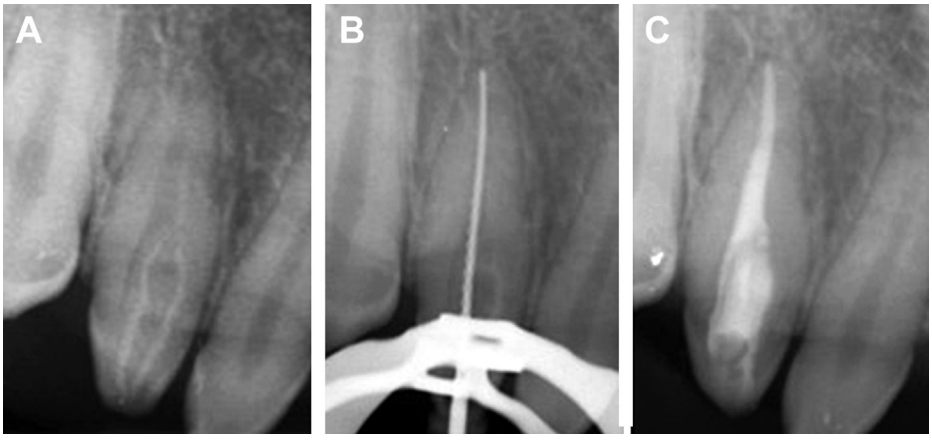

FIGURE 7 – (*A–C*) Management of type II dens invaginatus in which the invagination was incorporated in the final canal preparation. (courtesy Laura Lavigne).

FIGURE 8 – A radiopacifier has been added to the calcium hydroxide paste to improve observation of the filling of both true canal and invagination. (courtesy Gabriela Martin).

treated, preferably in a single visit. Because the invagination is restricted to the crown, the root canal anatomy is usually non-complicated, and treatment does not represent a big challenge. In teeth with an open apex, conservative pulp therapy is indicated (pulp capping or pulpotomy).

Necrotic Pulp

If the pulp becomes necrotic and apical periodontitis develops, both the invagination and root canal should be treated. The invagination should be approached as reported for teeth with irreversible pulpitis. However, disinfection of the true root canal is also essential for a favorable outcome and may require the use of intra-visit and/or inter-visit supplementary disinfection approaches. Teeth with an open apex should be treated by regenerative endodontics or apexification.

Type II Dens Invaginatus

The root canal system of teeth with type II dens invaginatus is usually not as complex as that of teeth with type III. In type II, the invagination penetrates the root and ends in a blind sac; it may assume either a lateral or a centered position in relation to the true root canal. In the former condition, the clinician usually does not have difficulties to access and treat the true

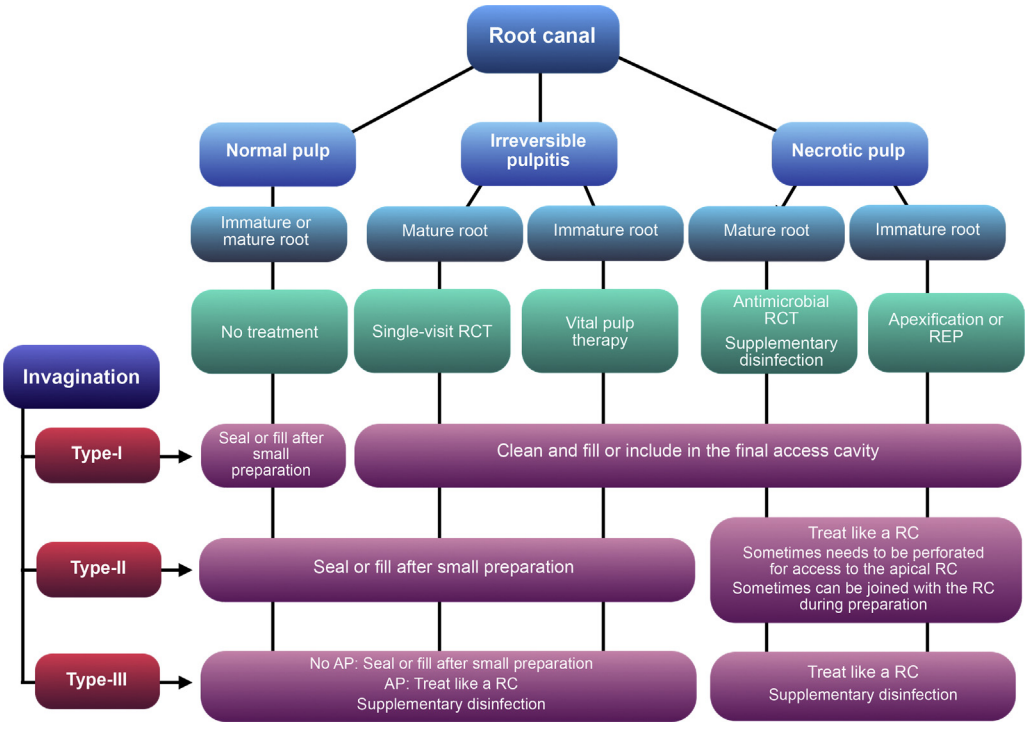

FIGURE 9 – Recommendations for management of teeth with dens invaginatus in different clinical conditions. Suggestive approaches are shown to deal with both the root canal and the invagination for the 3 types of dens invaginatus. AP, apical periodontitis; RC, root canal; RCT, root canal treatment; REP, regenerative endodontic procedures.

FIGURE 10 – In some cases of type II dens invaginatus with apical periodontitis, the apical terminus of the invagination has to be perforated to permit better access to the infection in the apical part of the true root canal. (courtesy Patrícia Ferrari).

canal. However, in the latter, the invagination usually "pushes" the true canal to the buccal or palatal/lingual root aspect, which presents a C shape around the invagination. Apically to the terminus of the invagination, the true canal usually assumes a natural round or oval morphology.

In some cases, the canal lumen in the C shape lateral to the invagination is so narrow that it is not negotiable with endodontic instruments. Consequently, in these cases, the clinician may perforate the apical terminus of the invagination to get access to the apical part of the true canal (Fig. 10). In other instances, depending on the extent, volume, and position of the dens invaginatus, the invagination can be entirely removed by using ultrasonic tips under magnification with the operating microscope[2,59]. However, treatment of the invagination and the true canal separately has been reported[54,60] and is a better approach to preserve tooth structure.

Vital Pulp

Non-inflamed pulp. As with type I, if the pulp is vital and healthy, only filling and sealing the invagination are indicated.

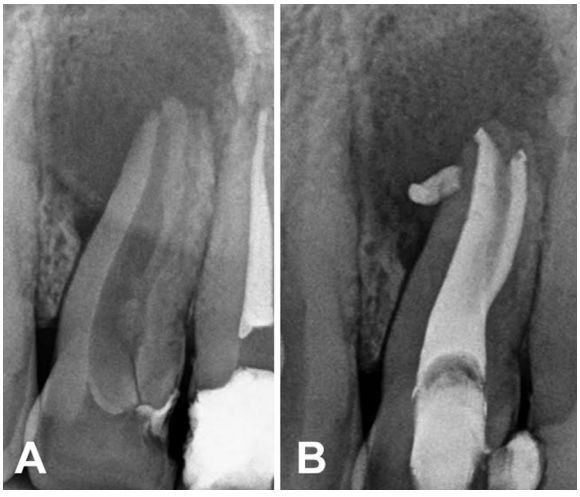

FIGURE 11 – Treatment of both the root canal and the invagination in a type III dens invaginatus with apical periodontitis. (*A*) Preoperative and (*B*) post-obturation images. (courtesy Cristina de La Roca).

Management of the invagination can be more complicated depending on how deep it extends into the root. The entrance of the invagination should be enlarged by using diamond burs or ultrasonic tips to permit access for debridement. If caries is detected at the entrance of the invagination, treatment should be as reported for type I. Ultrasonic tips and/or endodontic instruments associated with NaOCl or chlorhexidine irrigation should be used to clean the entire extent of the invagination. Next, the invagination should be filled with gutta-percha/sealer, MTA, or another bioceramic material or a restorative material (composite or glass ionomer). If pulpal exposure is suspected, already exists, or develops during the cleaning steps, the invagination should be preferably filled with MTA or another bioceramic material, which has been successfully used for vital pulp therapy[61,62]. Alternatively, the clinician may decide on performing nonsurgical root canal treatment in these teeth with pulp exposure. Eventually the coronal part of the invagination should be restored appropriately.

Inflamed pulp. Both the invagination and the true root canal should be treated. Special strategies, as discussed above, may be necessary to reach the true apical canal. In immature teeth, vital pulp therapy is indicated.

Necrotic Pulp. When apical periodontitis is detected and the pulp is necrotic, both the invagination and the true root canal should be treated separately if possible. However, in many cases, the invagination and the true canal need to be united to permit better access to the apical root canal. Because the anatomy is very complex and complicated in these cases and disinfection of the true root canal is paramount for a successful outcome, most of the strategies discussed above should be used, including CBCT-based planning, magnification with the operating microscope, supplementary disinfecting procedures, and thermoplasticized obturation. If the apex is immature, the clinician may opt for either a regenerative endodontic procedure or apexification.

Type III Dens Invaginatus

Most considerations for type II are also applied to type III dens invaginatus. One important exception is that the invagination directly contacts the apical or lateral periradicular tissues, and the treatment outcome will also depend on the proper management of the invagination. When apical periodontitis is present but the pulp is vital, then the cause of periradicular inflammation is bacterial infection of the invagination space. However, if the pulp is necrotic and apical periodontitis is detected,

it is clinically impossible to define whether the invagination, the true canal, or both, is the cause. Therefore, a successful outcome will rely on proper disinfection of both.

Vital Pulp

Non-inflamed pulp. If the pulp is vital and non-inflamed and there is no apical periodontitis, the management should be just preventive, as reported for the other 2 types. Cleaning, disinfecting and filling the invagination are of utmost importance to preserve pulpal vitality[63–65]. However, it is salient to point out that unlike the other types, in type III dens invaginatus, apical periodontitis may be present in a tooth with vital non-inflamed pulp. In these cases, the cause of the periradicular inflammatory lesion is bacterial infection of the invagination, which should be cleaned, shaped, disinfected, and filled like true root canals, with attention to its commonly aberrant anatomy. Pulp vitality of the true canal can be preserved, and treating only the invagination can result in periradicular healing[66].

Inflamed pulp. Both the true root canal and the invagination should be treated. In teeth with an open apex, pulpotomy may be the best approach for the inflamed pulp, whereas the invagination should be treated as a root canal.

Necrotic Pulp. Both the invagination and the true root canal system should be treated, with special emphasis on strategies to deal with bacterial infection in the complex anatomy of both (Fig. 11). Ideally, the canal and invagination should be treated separately, but sometimes they are inevitably communicated during preparation. Type III dens invaginatus cases with pulp necrosis and apical periodontitis are the most difficult to treat because the complex anatomy of both the root canal and the invagination makes cleaning, shaping, and disinfection very difficult. Therefore, the special treatment strategies to enhance infection control mentioned in the previous section are required to improve the chances for a satisfactory outcome, which is to save the tooth while maintaining it functional and surrounded by healthy periradicular tissues. If the apex is immature, regenerative endodontic or apexification procedures are indicated according to the stage of root development and root wall thickness.

CONCLUSIONS

Dens invaginatus is a developmental anomaly that predisposes the tooth to pulp and periradicular diseases. If endodontic treatment is required, it can be very challenging because of the anatomic complexity inherent to these cases. Therefore, it is important to understand the different manifestations and conditions that the clinician may face when dealing with this anomaly to apply therapeutic strategies that are more predictable to successfully treat and save teeth with dens invaginatus.

ACKNOWLEDGMENTS

This study was supported by grants from Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazilian governmental institutions.

The authors deny any conflicts of interest related to this study.

REFERENCES

1. Rotstein I, Llamosas E, Choi K-S. Endodontic therapy in teeth with anatomical variations. In: Rotstein I, Ingle JI, editors. Ingle's Endodontics. 7th ed. Raleigh, NC: PMPH USA; 2019. p. 866–9.
2. Sathorn C, Parashos P. Contemporary treatment of class II dens invaginatus. Int Endod J 2007;40:308–16.
3. Alani A, Bishop K. Dens invaginatus: part 1—classification, prevalence and aetiology. Int Endod J 2008;41:1123–36.
4. Hulsmann M. Dens invaginatus: aetiology, classification, prevalence, diagnosis, and treatment considerations. Int Endod J 1997;30:79–90.
5. Sarraf-Shirazi A, Rezaiefar M, Forghani M. A rare case of multiple talon cusps in three siblings. Braz Dent J 2010;21:463–6.
6. Zoya A, Ali S, Alam S, et al. Double dens invaginatus with multiple canals in a maxillary central incisor: retreatment and managing complications. J Endod 2015;41:1927–32.
7. Tebbutt J. Dental pathology: early identification. Br Dent J 2017;222:70.
8. Grahnen H, Lindahl B, Omnell K. Dens invaginatus: I—a clinical, roentgenological and genetical study of permanent upper lateral incisors. Odontol Revy 1959;10:115–37.
9. Kirzioglu Z, Ceyhan D. The prevalence of anterior teeth with dens invaginatus in the western Mediterranean region of Turkey. Int Endod J 2009;42:727–34.
10. Ricucci D, Milovidova I, Siqueira JF Jr. Unusual location of dens invaginatus causing a difficult-to-diagnose pulpal involvement. J Endod 2020;46:1522–9.
11. Rabinowitch BZ. Dens in dente: primary tooth—report of a case. Oral Surg Oral Med Oral Pathol 1952;5:1312–4.
12. Silberman A, Cohenca N, Simon JH. Anatomical redesign for the treatment of dens invaginatus type III with open apexes: a literature review and case presentation. J Am Dent Assoc 2006;137:180–5.
13. Oehlers FA. Dens invaginatus (dilated composite odontome): II—associated posterior crown forms and pathogenesis. Oral Surg Oral Med Oral Pathol 1957;10:1302–16.
14. Oehlers FA. Dens invaginatus (dilated composite odontome): I—variations of the invagination process and associated anterior crown forms. Oral Surg Oral Med Oral Pathol 1957;10:1204–18. contd.

15. Hallett GE. Incidence, nature, and clinical significance of palatal invaginations in the maxillary incisor teeth. Proc R Soc Med 1953;46:491–9.

16. Hegde V, Morawala A, Gupta A, Khandwawala N. Dens in dente: a minimally invasive nonsurgical approach! J Conserv Dent 2016;19:487–9.

17. Patel S. The use of cone beam computed tomography in the conservative management of dens invaginatus: a case report. Int Endod J 2010;43:707–13.

18. Oehlers FA. The radicular variety of dens invaginatus. Oral Surg Oral Med Oral Pathol 1958;11:1251–60.

19. Zhu J, Wang X, Fang Y, et al. An update on the diagnosis and treatment of dens invaginatus. Aust Dent J 2017;62:261–75.

20. Gallacher A, Ali R, Bhakta S. Dens invaginatus: diagnosis and management strategies. Br Dent J 2016;221:383–7.

21. Ranganathan J, Rangarajan Sundaresan MK, Ramasamy S. Management of Oehler's type III dens invaginatus using cone beam computed tomography. Case Rep Dent 2016;2016:3573612.

22. Tan X, Zhang L, Zhou W, et al. Palatal radicular groove morphology of the maxillary incisors: a case series report. J Endod 2017;43:827–33.

23. Gotoh T, Kawahara K, Imai K, et al. Clinical and radiographic study of dens invaginatus. Oral Surg Oral Med Oral Pathol 1979;48:88–91.

24. Cantín M, Fonseca GM. Dens invaginatus in an impacted mesiodens: a morphological study. Rom J Morphol Embryol 2013;54:879–84.

25. Rushton MA. Invaginated teeth (dens in dente): contents of the invagination. Oral Surg Oral Med Oral Pathol 1958;11:1378–87.

26. Zehnder MS, Connert T, Weiger R, et al. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. Int Endod J 2016;49:966–72.

27. Jain SD, Carrico CK, Bermanis I. 3-Dimensional accuracy of dynamic navigation technology in locating calcified canals. J Endod 2020;46:839–45.

28. Chong BS, Dhesi M, Makdissi J. Computer-aided dynamic navigation: a novel method for guided endodontics. Quintessence Int 2019;50:196–202.

29. Ali A, Arslan H. Guided endodontics: a case report of maxillary lateral incisors with multiple dens invaginatus. Restor Dent Endod 2019;44:e38.

30. Girsch WJ, McClammy TV. Microscopic removal of dens invaginatus. J Endod 2002;28:336–9.

31. Falcao Lde S, de Freitas PS, Marreiro Rde O, Garrido AD. Management of dens invaginatus type III with large periradicular lesion. J Contemp Dent Pract 2012;13:119–24.

32. Siqueira JF Jr, Rôças IN. Optimising single-visit disinfection with supplementary approaches: a quest for predictability. Aust Endod J 2011;37:92–8.

33. Paiva SS, Siqueira JF Jr, Rôças IN, et al. Clinical antimicrobial efficacy of NiTi rotary instrumentation with NaOCl irrigation, final rinse with chlorhexidine and interappointment medication: a molecular study. Int Endod J 2013;46:225–33.

34. Huffaker SK, Safavi K, Spångberg LS, Kaufman B. Influence of a passive sonic irrigation system on the elimination of bacteria from root canal systems: a clinical study. J Endod 2010;36:1315–8.

35. Siqueira JF Jr, Magalhães KM, Rôças IN. Bacterial reduction in infected root canals treated with 2.5% NaOCl as an irrigant and calcium hydroxide/camphorated paramonochlorophenol paste as an intracanal dressing. J Endod 2007;33:667–72.

36. Shuping GB, Orstavik D, Sigurdsson A, Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. J Endod 2000;26:751–5.

37. Carvalho APL, Nardello LCL, Fernandes FS, et al. Effects of contemporary irrigant activation schemes and subsequent placement of an interim dressing on bacterial presence and activity in root canals associated with asymptomatic apical periodontitis. J Clin Med 2020;9:854.

38. Siqueira JF Jr. Treatment of Endodontic Infections. London: Quintessence Publishing; 2011.

39. Wadachi R, Araki K, Suda H. Effect of calcium hydroxide on the dissolution of soft tissue on the root canal wall. J Endod 1998;24:326–30.

40. Hasselgren G, Olsson B, Cvek M. Effects of calcium hydroxide and sodium hypochlorite on the dissolution of necrotic porcine muscle tissue. J Endod 1988;14:125–7.

41. Weller RN, Kimbrough WF, Anderson RW. A comparison of thermoplastic obturation techniques: adaptation to the canal walls. J Endod 1997;23:703–6.

42. Keles A, Alcin H, Kamalak A, Versiani MA. Micro-CT evaluation of root filling quality in oval-shaped canals. Int Endod J 2014;47:1177–84.

43. Steffen H, Splieth C. Conventional treatment of dens invaginatus in maxillary lateral incisor with sinus tract: one year follow-up. J Endod 2005;31:130–3.

44. Norouzi N, Kazem M, Gohari A. Nonsurgical management of an immature maxillary central incisor with type III dens invaginatus using MTA plug: a case report. Iran Endod J 2017;12:521–6.

45. Plascencia H, Díaz M, Moldauer BI, et al. Non-surgical endodontic management of type II dens invaginatus with closed and open apex. Iran Endod J 2017;12:534–9.

46. Jung M. Endodontic treatment of dens invaginatus type III with three root canals and open apical foramen. Int Endod J 2004;37:205–13.

47. Altuntas A, Cinar C, Akal N. Endodontic treatment of immature maxillary lateral incisor with two canals: type 3 dens invaginatus. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:e90–3.

48. Liu J, Zhang YR, Zhang FY, et al. Microscopic removal of type III dens invaginatus and preparation of apical barrier with mineral trioxide aggregate in a maxillary lateral incisor: a case report and review of literature. World J Clin Cases 2020;8:1150–7.

49. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha: a retrospective clinical study. Endod Dent Traumatol 1992;8:45–55.

50. Kim SG, Malek M, Sigurdsson A, et al. Regenerative endodontics: a comprehensive review. Int Endod J 2018;51:1367–88.

51. Yang J, Zhao Y, Qin M, Ge L. Pulp revascularization of immature dens invaginatus with periapical periodontitis. J Endod 2013;39:288–92.

52. Kumar H, Al-Ali M, Parashos P, Manton DJ. Management of 2 teeth diagnosed with dens invaginatus with regenerative endodontics and apexification in the same patient: a case report and review. J Endod 2014;40:725–31.

53. American Association of Endodontists (AAE). Clinical Considerations for a Regenerative Procedure. 2016. Available at: https://www.aae.org/uploadedfiles/publications_and_research/research/currentregenerativeendodonticconsiderations.pdf. Accessed Jnauary 11, 2021.

54. Subay RK, Kayatas M. Dens invaginatus in an immature maxillary lateral incisor: a case report of complex endodontic treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102:e37–41.

55. Reddy YP, Karpagavinayagam K, Subbarao CV. Management of dens invaginatus diagnosed by spiral computed tomography: a case report. J Endod 2008;34:1138–42.

56. Vieira GCS, Antunes HS, Perez AR, et al. Molecular analysis of the antibacterial effects of photodynamic therapy in endodontic surgery: a case series. J Endod 2018;44:1593–7.

57. de Sousa SM, Bramante CM. Dens invaginatus: treatment choices. Endod Dent Traumatol 1998;14:152–8.

58. Bishop K, Alani A. Dens invaginatus: part 2—clinical, radiographic features and management options. Int Endod J 2008;41:1137–54.

59. Kristoffersen O, Nag OH, Fristad I. Dens invaginatus and treatment options based on a classification system: report of a type II invagination. Int Endod J 2008;41:702–9.

60. Tsurumachi T, Hayashi M, Takeichi O. Non-surgical root canal treatment of dens invaginatus type 2 in a maxillary lateral incisor. Int Endod J 2002;35:310–4.

61. Mente J, Geletneky B, Ohle M, et al. Mineral trioxide aggregate or calcium hydroxide direct pulp capping: an analysis of the clinical treatment outcome. J Endod 2010;36:806–13.

62. Pitt Ford TR, Torabinejad M, Abedi HR, et al. Using mineral trioxide aggregate as a pulp-capping material. J Am Dent Assoc 1996;127:1491–4.

63. Gound TG, Maixner D. Nonsurgical management of a dilacerated maxillary lateral incisor with type III dens invaginatus: a case report. J Endod 2004;30:448–51.

64. Pitt Ford HE. Peri-radicular inflammation related to dens invaginatus treated without damaging the dental pulp: a case report. Int J Paediatr Dent 1998;8:283–6.

65. Goncalves A, Goncalves M, Oliveira DP, Goncalves N. Dens invaginatus type III: report of a case and 10-year radiographic follow-up. Int Endod J 2002;35:873–9.

66. Schwartz SA, Schindler WG. Management of a maxillary canine with dens invaginatus and a vital pulp. J Endod 1996;22:493–6.