DIAGNOSIS OF DENS INVAGINATUS USING CBCT: A SYSTEMATIC LITERATURE REVIEW OF HUMAN STUDIES

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Abstract

Background: Dens Invaginatus (DI) is a dental anomaly characterized by the inward folding of the inner dental epithelial tissue before tooth mineralization begins. It primarily affects permanent maxillary lateral incisors but can also occur in primary teeth and other dental arches. **Objective:** This systematic review evaluates the utility of Cone Beam Computed Tomography (CBCT) in diagnosing and managing DI, providing insights into effective endodontic practices for this condition. **Methods:** The review followed the PRISMA guidelines, including 32 case reports and case series published between 1994 and 2023. Studies were selected based on their focus on human subjects, endodontic management of DI, and the use of CBCT for diagnosis. Exclusion criteria included studies on deciduous teeth, non-English publications, and prevalence studies. Data were extracted on study population characteristics, diagnostic methods, and treatment modalities. **Results:** CBCT was found to significantly enhance the precision of DI diagnosis and treatment planning by providing detailed three-dimensional imaging. This imaging modality was particularly beneficial in cases involving complex root canal configurations. Despite the higher radiation dose compared to conventional radiography, CBCT's detailed imaging capabilities improved the assessment of the invagination's extent and its relationship with adjacent structures, leading to better treatment outcomes. **Conclusion:** CBCT represents a major advancement in endodontic diagnostics and management of DI, offering comprehensive imaging that enhances diagnostic accuracy and treatment efficacy. While CBCT should be used judiciously due to its higher radiation exposure, its benefits in managing DI make it an invaluable tool in modern dentistry. Continued research and clinical application will further refine CBCT's role in optimizing the management of DI.

Keywords: Cone Beam Computed Tomography (CBCT), Dens Invaginatus (DI), Diagnosis, Endodontic Management, Imaging.

INTRODUCTION

Dens Invaginatus (DI) is characterized by the inward folding of the inner dental epithelial tissue (dental papilla) before mineralization begins. The condition was first identified by a dentist in 1856 [1]. In 1873, Muhlreiter described it as “anomalous cavities in human teeth” [2]. Later, in 1955, Salter referred to it as a “tooth within a tooth” [3].

This type of malformation was also noted by Plaquet in a whale’s tooth in 1974 [4, 5]. DI involves the enamel folding into the dentin, creating a pocket or dead space, which occurs before the calcification of the crown [6, 7]. The permanent maxillary lateral incisor is most frequently affected, although it can also be found in primary teeth and in both maxillary and mandibular arches [8]. Often, it is seen as an enhancement in the development of a lingual pit [9].

Various terms have been suggested for DI, including “dens in dente” due to its radiographic appearance of a tooth within a tooth, “dilated composite odontome” due to abnormal dilation of the dental papilla, “invaginated odontome,” “dilated gestantodontome,” “telescope teeth,” “tooth inclusion,” “dentoid in dente,” and “warty tooth” [1, 10, 11] .

The occurrence of dens Invaginatus (DI) is thought to stem from embryological factors, specifically the stimulation and subsequent proliferation of enamel organ cells into the dental papilla during development [12]. Kronfeld (1934) offered a different perspective, suggesting that DI results from inhibited growth in a localized cluster of cells, while surrounding cells continue to grow normally [13]. Atkinson (1943) attributed the anomaly to external pressures on the developing tooth germ [14].

These pressures could come from nearby tooth germs, such as the central incisor or canine, which develop at least six months earlier than the lateral incisor, or from other factors like trauma [15] . Kronfeld also noted that the invagination contains remnants of the dental papilla or periodontal connective tissue upon eruption, which can become necrotic and provide a nutrient-rich environment conducive to bacterial contamination from the mouth [14].

The invagination in dens invaginatus (DI) is typically tear-shaped and enclosed by calcified dental tissue in mild cases, while more severe instances may result in a fissure that communicates with the periodontal ligament. The invagination can also be associated with changes in the morphology of the root canal. A study by De Smit and Demaut on extracted, root-filled invaginated teeth found that the root canal was irregular in cross-section, featuring wave-like constrictions and dilations [16].

Additionally, reports by Walvekar and Behbehani (1997) indicated that multiple root canals could be associated with the invagination [17]. In contrast, some studies have shown the invaginated surface to be uniform and regular, with no communication with the pulp [18]. Kramer (1953) noted that defects in the enamel layer's structure were confined to the invagination, with the dentine intact but exposed [19]. He concluded that the absence of enamel in these areas allows dentine tubules to be contaminated by bacteria, providing a direct pathway for pulpal infection [19]. Furthermore, a scanning electron microscopy (SEM) study by Morfis in 1993 described changes in the chemical structure of the enamel within the defect [20]. Despite the limitations of these studies, the consensus is that teeth affected by DI are at an increased risk of developing pulpal problems [18].

Inherently poor anatomical features at both macro and microscopic levels facilitate bacterial contamination, leading to a higher risk of pulpal complications. The following conditions are often associated with dens invaginatus (DI): microdontia, macrodontia, hypodontia, oligodontia, taurodontism, germination, fusion, supernumerary teeth, dentinogenesis imperfecta, odontoma, coronal agenesis, shovel-shaped incisors, mesiodens, obliterated pulp chambers, C-shaped canal configurations, palato radicular groove defect, short root anomaly, dilacerations, albinism, periodontal abscess, multiple root canals, cranial suture syndromes, unicystic ameloblastoma, and coronal fractures [21].

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Classification

Hallet introduced the first classification of dens Invaginatus (DI) in 1953, delineating four types of invaginations based on clinical and radiographic criteria [22]. Schulze and Brand (1972) later proposed a classification system that included twelve variations in the clinical and radiographic appearance of invaginations [23].

However, the most widely accepted classification system is the one developed by Oehlers in 1957, known for its clear and straightforward language. According to Oehlers' classification:

Type I: The invagination is small, enamel-lined, and restricted inside the tooth's crown, not extending beyond the exterior amelo-cemental junction.

Type II: The invagination is enamel-lined and extends into the pulp chamber, but it remains inside the root canal and does not communicate with the periodontal ligament.

Type IIIA: The invagination continues into the root and interacts laterally with the periodontal ligament area via a pseudo-foramen. Typically, there is no communication with the pulp, which is crushed within the roots.

Type IIIB: The invagination spreads into the root and connects to the periodontal ligament via the apical foramen. Usually there is no connection with the pulp [24].

Dilated Odontoma

Dens Invaginatus (DI) is also a variation that causes expansion of the impacted tooth's crown and/or root. The most severe expression of this larger variety is known as dilated odontoma, however it is not definitely defined as a distinct entity in current classifications of odontogenic tumors. Dilated odontoma has a complicated structure with significant invagination, which frequently contains center soft and/or hard tissue. examples of dilated odontoma in the mandibular molar area are uncommon, with just a few examples recorded in recent literature [25].

DI Associated with Supernumerary Tooth

A supernumerary tooth is a developmental anomaly characterized by the presence of an extra tooth in addition to the conventional series [26]. Supernumerary teeth located abnormally between the central maxillary incisors are referred to as mesiodens due to their central position.

They are categorized based on shape and size into eumorphic (resembling normal central incisors) or dysmorphic (varying in size and shape) types [27]. The etiology is widely attributed to hyperactivity of the dental lamina, with genetic and environmental factors playing significant roles in human odontogenesis [27]. Extraction of mesiodens is recommended to prevent potential impacts on adjacent teeth and cyst formation in children and adolescents.

Early extraction during the mixed dentition phase is also advised to facilitate spontaneous eruption and alignment of incisors [27]. There are limited reports in recent literature on the association between mesiodens and dens invaginatus (DI). Gross appearance of supernumerary teeth often shows a premolar-shaped crown with four pits and a single short root with a wide-open apex.

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Occurrence and Prevalence

Dens Invaginatus (DI) exhibits a wide variation in occurrence, ranging from 0.04% to 26% in the Indian population [28, 7]. The condition predominantly affects permanent maxillary lateral incisors, with reported prevalence rates of 47%, and it often occurs bilaterally in 43% of cases [29].

In other populations, DI is notably prevalent in the Japanese (4%-39%), Turkish (12%), Saudi Arabian (10%), and United States populations (8%) [10, 30]. Type 1 DI is the most commonly observed form, accounting for 94% of cases, followed by Type 3 (33%) and Type 2 (4%) [30].

The anomaly is rare in the mandible, with reported cases involving central incisors, lateral incisors (each 1 case), canines (1 case), premolars (5 cases, 2 bilateral), and mandibular third molars (1 case) [31]. In deciduous teeth, DI has been reported in second molars, maxillary canines, mandibular canines, and maxillary central incisors [8, 3].

Diagnosis

Cone beam computed tomography (CBCT) is preferred over Spiral Computed Tomography for diagnosing and managing dens invaginatus (DI) due to its advantages of lower radiation dose, reduced scanning time, and higher resolution and accuracy [33]. CBCT enables precise analysis with thin slices, facilitating effective endodontic treatment, even in complex cases. It plays a crucial role in evaluating the connection between the invagination and root canal, which is essential for managing periapical lesions [34].

Specifically, CBCT is valuable in treating complex root canal configurations seen in Coronal DI Type II and III, accurately depicting the location and relationships of the invagination with the main canal [35].

Among three-dimensional imaging techniques, CBCT stands out for imaging intricate root canal systems while exposing patients to relatively lower radiation doses. Research indicates that conventional 2D radiographs often fail to provide comprehensive information about invagination and its relationship with the root canal.

In contrast, CBCT reveals detailed structures, showing separate invaginations that can hinder effective cleaning and disinfection of infected canals, thereby contributing to successful DI treatment outcomes [35].

Furthermore, CBCT reconstructed images allow precise analysis of the invagination's nature and its communication with the main canal, guiding treatment decisions aimed at preserving the root canal integrity and reducing the risk of tooth fracture [36].

Despite its advantages, CBCT does carry a higher radiation dose compared to traditional 2D radiographs, which sparks debate over its routine use in endodontics. Therefore, CBCT should be selectively recommended based on its significant benefits over conventional imaging techniques tailored to individual patient needs [37].

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METHODOLOGY

The systematic review protocol adhered to the PRISMA checklist and utilized the PICO framework to formulate the research question: "Can dens Invaginatus (DI) be assessed and managed using cone beam computed tomography (CBCT) in the human population?"

Study Design, Sampling, and Setting: The review included thirty-two case reports and was structured as a systematic literature review.

Protocol: Conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Eligibility Criteria: Abstracts and titles of identified studies were screened electronically and manually. Inclusion criteria specified studies involving human subjects, focusing on endodontic management of DI, participants aged >15 years, clinical studies published in English between 1994 and June 2019. Exclusion criteria encompassed studies on deciduous teeth, patients below 15 years, in vitro and animal studies, non-English publications, and prevalence studies.

Sources of Information: Electronic searches were performed on PubMed and Ebscohost databases, supplemented by manual searches of reference lists from selected articles.

Literature Search Strategy: The search strategy employed Mesh terms and keywords combined with Boolean operators "AND" and "OR" to optimize database searches. Data collected underwent manual review to identify and eliminate duplicates, and final selection was based on the PRISMA checklist.

Study Selection: Two-stage study selection process: Stage 1 involved screening titles/abstracts for relevance to eligibility criteria. Full texts were retrieved when necessary for further evaluation. Stage 2 entailed full-text review, applying the same eligibility criteria to determine inclusion.

Data Extraction and Data Items: Data extracted from selected studies included author(s) and year of publication, country, journal, study population characteristics, tooth number affected, diagnostic methods employed, and treatment modalities utilized.

This systematic review aimed to comprehensively evaluate the utility of CBCT in diagnosing and managing DI, providing insights into effective endodontic practices for this dental anomaly.

RESULTS

The search approach is illustrated in Figure 1. The total number of relevant articles identified through electronic database searches and human searches was 853. Duplicate articles were eliminated. After removing duplicates, 467 articles were considered for abstract review. After full text analysis, thirty-two papers were removed, leaving just 32 articles in the systematic review. (Figure 1)

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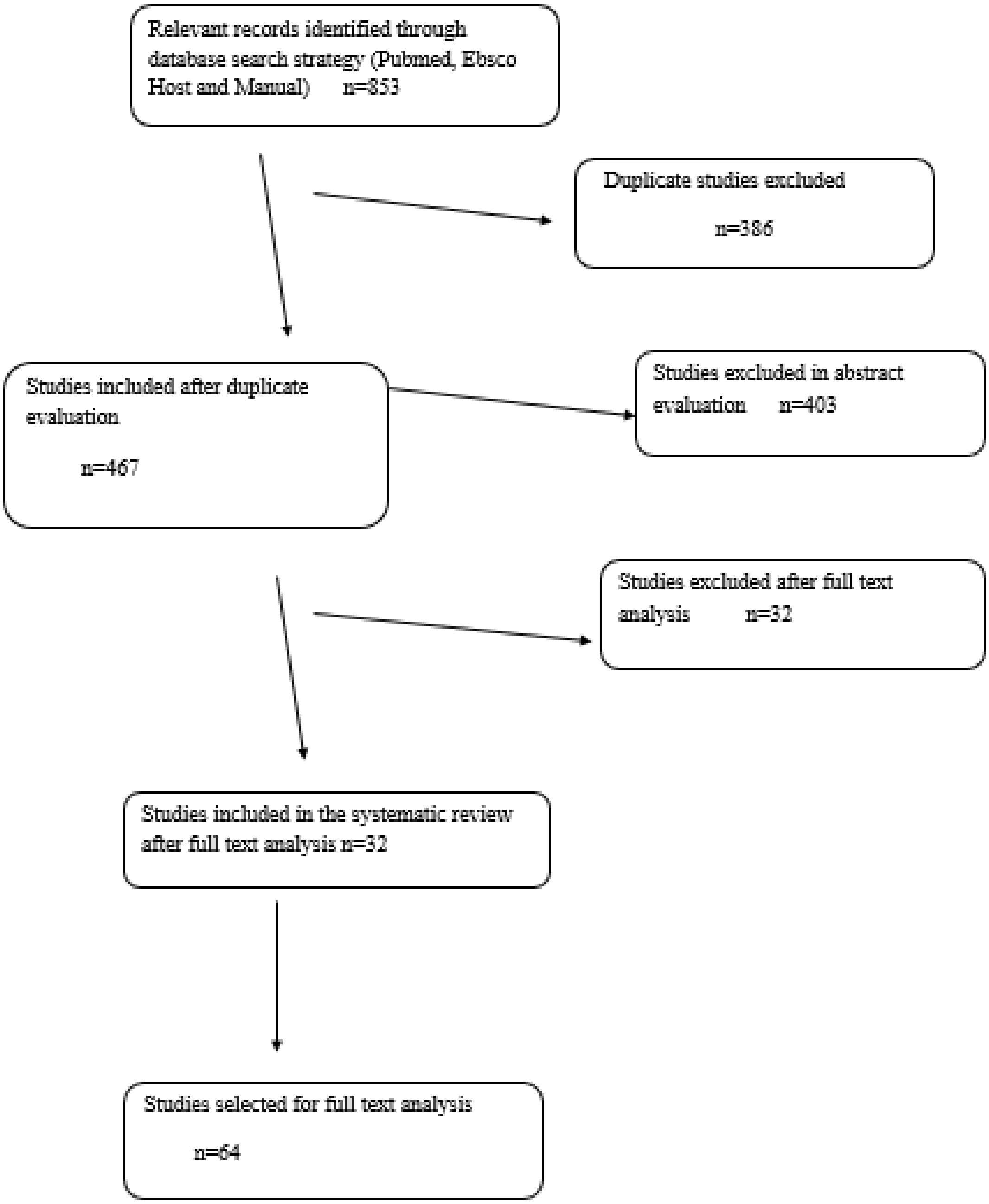

Figure 1 - Data Framed In Prisma Flowchart

Characteristics of the included studies

Characteristics of the included studies are detailed in Tables 1 and 2 [38-70]. Thirty of the 32 articles were case reports, while the remaining two were case series. All studies were published in English, spanning from 1994 to 2023.

Table 1: Characteristics of 32 Studies Which Used Cbct for the Diagnosis of Dens Invaginatus(Part 1)

Author	Journal	Population	Tooth No.	Diagnostic Test	Diagnosis	Age/ Gender	Country	Treatment	Ref.
YJ Lim (2011)	Restorative Dentistry & Endodontics	Korean	46	CBCT	DI	12/F	Korea	RCT	[38]
K Pradeep (2012)	Journal Of Clinical Imaging Science	Indian	22	CBCT	Type III DI	18/F	India	RCT	[39]
I.J. Inojosa (2012)	International Journal of Clinical Dentistry	-	11,12	CBCT	Type III DI	29/F	Brazil	RCT	[40]
A.Subbiya (2013)	Journal of clinical and diagnostic research	Indian	22	CBCT	Type II DI	16/F	India	RCT	[41]
Hiroshi Kato(2013)	Bull Tokyo Dent Coll	Japanese	12	CBCT	Type III DI	16/F	Tokyo	RCT	[42]
Shanmugam Jaikailash (2014)	Journal Of Conservative Dentistry	Indian	12	CBCT	Type III DI	17/M	India	RCT	[43]
KT Ceyhanli (2014)	Journal of Oral Science	Turkish	22	CBCT	Type III DI	17/F	Turkey	RCT	[44]
PC.Baz (2014)	Quintessence	Spanish	21	CBCT	DI	28/M	Spain	RCT	[45]
Sosa(2014)	Journal Of Endodontics		12,12,22	CBCT	Type I,II DI	47,17,1 9/M,M,F		RCT, RCT, RCT followed by surgery	[46]
Renjith George Pallivathukal (2015)	BMJ case report	Malaysian	12	CBCT	DI Type 3b in geminated Type 1	19/F	Malaysia	RCT followed by surgery	[47]
Maryam Forghani (2015)	International Endodontic Journal	Iranian	22	CBCT	DI Type III with C shaped canals	18/F	Iran	RCT	[48]
Ali Nosrat (2015)	Journal Of Endodontics	-	12	CBCT	DI	16/M	Maryland	RCT	[49]
A.Z.Macho	JADA	Spanish	22	CBCT	DI	22/F	Spain	RCT	[50]
Nupur (2015) Kharangate (2015)	Contemporary Clinical Dentistry	Indian	35,45	CBCT	Type I DI	25/M	India	RCT	[51]
A.Zoya (2015)	Journal of Endodontics	Indian	11	CBCT	Type IIIB , II	16/F	India	RCT followed by surgery	[52]
V.Naga Lakshmi (2016)	Journal Of Conservative Dentistry	Indian	22	CBCT	DI Type II and periapical pathosis	20/M	India	RCT	[55]

Table 2: Characteristics Of 32 Studıes Which Used Cbct For The Diagnosis Of Dens Invaginatus (Part 2)

Author	Journal	Population	Tooth No.	Diagnostic Test	Diagnosis	Age/ Gender	Country	Treatment	Ref.
JNR Martins (2016)	European Journal Of Dentistry	Portuguese	12	CBCT	Type III DI	15/F	Spain	RCT	[56]
Ruchi Juneja (2016)	Journal of clinical & diagnostic Research	Indian	42	CBCT	TypeIII DI	22/M	India	RCT	[57]
K.Mensch (2016)	Japanese Society for oral and Maxillofacil Radiology and Springer Japan	Japanese	12	CBCT	DI	26/F	Japan	RCT	[58]
Shaik Izaz (2017)	Journal of Dental Shiraz University of medical sciences	Indian	12	CBCT	DI Type III	28/M	India	RCT	[59]
Ping Zang (2017)	Journal Of Endodontics	Chinese	41	CBCT	DI with pulp necrosis and apical periodontitis	26/M	China	RCT followed by surgery	[60]
Ramin Abazarpour (2017)	Iranian Endodontic Journal	Iranian	25	CBCT	DI Type II	19/F	Iran	RCT	[62]
Hela Zekri (2017)	Dental,Oral and Craniofacial Research	-	12, 11,12,2 2	CBCT	TypeII DI,TypeI DI,Type III DI	18,17,20/ F,F,F	Tunisia	RCT,RCT,R CT	[63]
Evaldo Almeida Rodrigues (2018)	Operative Dentistry and Endodontics	Brazilian	12	CBCT	DI Type II	22/F	Brazil	RCT	[64]
Vishnupriya Koteeswaran (2019)	Journal Of Conservative Dentistry	Indian	21	CBCT	Double DI	24/M	India	RCT	[65]
Zahi Badran (2019)	European Journal Of Dentistry	-	21	CBCT	Atypical buccal DI	23/M	France	Surgery	[66]
M.P.Liji (2019)	Journal Of Conservative Dentistry	Indian	11	CBCT	Type II canal configuration and Type I DI	28/F	India	RCT	[67]
Swati Borkar (2019)	Contemporary clinical Dentistry	Indian	34	CBCT	Type II DI	30/F	India	RCT followed by surgery	[68]
M.Solomonov (2019)	Journal Of Conservative Dentistry	-	12	CBCT	Type III DI	22/M	Israel	RCT	[69]
Sidhartha Sharma (2019)	Journal Of Conservative Dentistry	Indian	16	CBCT	Type III DI	22/F	India	RCT	[70]

DISCUSSION

In the field of Endodontics, cone beam computed tomography (CBCT) has significantly advanced the ability to plan, diagnose, treat, and predict outcomes in cases involving complex conditions like anatomical anomalies, including dens invaginatus (DI). CBCT plays a crucial role in identifying the specific type of DI, assessing the dimensions of the invagination, determining any associated bone lesions, and monitoring healing progress [7].

Treating primary teeth affected by DI is generally straightforward. Extraction may be necessary if the periapical lesion impacts the permanent tooth germ. Otherwise, treatment options vary based on pulp condition, ranging from composite resin restoration to root canal treatment (RCT). In cases where DI affects supernumerary teeth, these are typically found in the maxillary anterior region. Managing issues such as impaction or crowding of normal maxillary incisors often involves extracting supernumerary teeth. However, if extraction is declined by the patient or if the supernumerary teeth have no impact on the normal dentition, treatment strategies similar to those used for permanent teeth with DI are pursued [7].

Integrating the metaverse, AI, and blockchain technology into the diagnosis of dens invaginatus using Cone Beam Computed Tomography (CBCT) can significantly enhance precision and efficiency. The metaverse enables immersive 3D visualization of CBCT scans, allowing dental professionals to examine intricate details of tooth anatomy in a virtual environment, leading to more accurate diagnoses [71]. AI algorithms can further analyze CBCT images, identifying subtle anomalies and patterns indicative of dens invaginatus, thus aiding in early and accurate detection. Blockchain technology ensures the secure and immutable storage of CBCT data and diagnostic records, facilitating seamless sharing and collaboration among dental specialists while maintaining data integrity and patient privacy [72,73]. Together, these technologies offer a comprehensive approach to improving the diagnostic accuracy and management of dens invaginatus.

DI type I

In DI type I, the invagination is confined to the crown and is minimal. When the pulp is not infected, prophylactic filling is preferred. However, if the entrance of the invagination is too small to be checked clinically, then prophylactic filling is not suitable. In such cases, the pits and fissures are filled with fissure sealant. Periodic follow up is essential for patients who opt for preventive treatment. Endodontic treatment needs to be performed, if pulp disease exists. Depending on the extent of pulpal infection and the status of the apical foramen, the treatment varies. For teeth with limited pulpitis, especially for immature teeth, pulpotomy should be the treatment of choice. If the pulp is infected extensively or a periapical lesion exists, RCT is needed. Apexification is more appropriate, if the affected tooth has extensive pulpitis or a periapical lesion. Only in cases, where endodontic treatment fails to control symptoms, surgery is recommended and is always combined with endodontic treatment.[2,21]

DI type II

The degree of severity of invagination in Coronal Dens Invaginatus (CDI) type II exceeds that of CDI type I, involving the pulp chamber and perhaps joining with it. Preventive filling is advised for teeth having pits or grooves on the lingual or occlusal surfaces that do not have caries, similar to CDI type I. If caries are present near the invagination's entry and the pulp is still viable, treatment should be directed toward the invagination. Mineral trioxide aggregate (MTA) is recommended for its superior biocompatibility and antibacterial characteristics. Successful examples of employing MTA to fill invaginations in teeth with CDI type II, with one-year follow-ups revealing good pulp results, support MTA as the appropriate filler material in these circumstances. Therefore, MTA is advised for teeth with CDI type II.

CDI type II, where the invagination spreads deeper into the root, requires more sophisticated therapy than CDI type I. Some cases have reported that the invaginated canal and the main canal were filled separately without the invagination being removed [21]. While preserving the invagination may strengthen the root, remaining material within it might obstruct cleaning and filling of the main root canal, potentially influencing the outcome. This complication required surgical intervention in two instances from prior research [21]. If the invagination is close to the enamel-cementum junction, it is best removed during coronal flaring. Endodontists have effectively excised invaginations using ultrasonic procedures under a microscope while maintaining considerable tissue.[2,21].

Apexification is recommended in immature roots because it promotes additional root growth. Recent research has demonstrated that constructing an apical plug with calcium hydroxide or MTA can effectively treat juvenile teeth with CDI type II and periapical lesions. This method efficiently reduces periapical radiolucency and preserves the integrity of the root canal walls with minimal debridement.[2,21].

CDI TYPE III

This kind of dens invaginatus (DI), notably CDI type III, has a more complicated root canal anatomy that requires comprehensive three-dimensional imaging for accurate diagnosis and treatment planning. Clinically, many CDI type III teeth have pulpal disease or periapical lesions. A critical component of treatment planning is precisely analyzing the state of the primary pulp. When the main pulp is healthy, the invaginated canal must be thoroughly cleaned and densely filled to maintain its vitality. If both the main canal and the invaginated canal are diseased, each channel must be debrided individually and densely filled.

Apexification is advised for young main canals with a wide-open apex. However, if the invagination has a large open foramen and is positioned laterally to the main canal, apexification of the invaginated canal frequently fails to establish a hard tissue barrier. Mineral trioxide aggregate (MTA) is commonly employed to form an apical barrier in such cases [2, 21].

Relevant articles were found and manually filtered after conducting a comprehensive database search. In addition, the bibliographies of relevant papers and review articles were reviewed to ensure that the data was correct and relevant. The results were then structured according to the PRISMA Flowchart principles.

CONCLUSION

Dens Invaginatus (DI) represents a significant dental anomaly characterized by the invagination of the enamel organ into the dental papilla before tooth mineralization begins. This condition, although relatively common in permanent teeth, particularly affects the maxillary lateral incisors. Various classification systems, notably Oehlers' classification, categorize DI based on the extent of invagination and its clinical implications.

The use of Cone Beam Computed Tomography (CBCT) has emerged as a valuable tool in the diagnosis and management of DI. CBCT offers detailed three-dimensional imaging, which enhances the precision of treatment planning by accurately delineating the extent of the invagination and its relationship with adjacent dental structures. This imaging modality is particularly beneficial in cases involving complex root canal configurations associated with DI, facilitating effective endodontic interventions and reducing the risk of complications.

The systematic review conducted for this study synthesized evidence from 32 clinical studies and case reports, highlighting CBCT's effectiveness in diagnosing and managing DI across different populations and clinical settings. Despite its advantages, CBCT does entail higher radiation exposure compared to conventional radiography, necessitating judicious use based on individual patient needs and clinical indications.

In conclusion, CBCT represents a significant advancement in the field of Endodontics, offering comprehensive imaging capabilities that contribute to improved diagnostic accuracy and treatment outcomes in cases of DI. Continued research and clinical application of CBCT will further refine its role in optimizing the management of this challenging dental anomaly.

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