Abstract

Aim Dens Invaginatus (DI) is a rare malformation of the teeth, showing a broad spectrum of morphologic variations. The aim of this study was to perform in vitro radiographic analyses of three extracted dens invaginatus (DI) teeth with complex root anatomy using plain radiographs, CBCT, MRI and micro CT techniques.

Materials and methods Study Design: Three maxillary lateral incisors (A, B and C) from two patients were extracted due to poor prognosis and were radiographically analysed. Initially, conventional two dimensional digital radiographs were taken. Subsequently CBCT, micro CT and MRI analyses were performed.

Results According to the Schulze and Brand system of classification, teeth A, B and C were classified as A2, B3 and B2 respectively. To detect the relationship between the invagination to the oral cavity and pulp chamber, conventional two dimensional radiographs were of no help. CBCT and MRI images were found to be complementary to each other but provided lesser structural detail than micro CT images.

Conclusion Reporting on these three DI teeth, normal conventional radiographs did not provide detailed structural information about the malformation due to geometric distortion and lack of information. Even though Oehler classification system is the most widely used, classification by Schulze and Brand is more applicable in rare and deviant teeth.

Keywords CBCT; Dens invaginatus; Micro CT; MRI.

In vitro analysis of extracted dens invaginatus using various radiographic imaging techniques

Introduction

Dens Invaginatus (DI) is a rare malformation of the teeth, showing a broad spectrum of morphologic variations [Hulsmann, 1997]. It was described for the first time in 1794 by Ploquet who found this malformation in a whale’s tooth. This defect was first reported in humans in 1859 by Tomes [Kitchin, 1949] and is ever since known to the dental profession by numerous names as coronal odontomas, invaginated odontoma, deep foramen caecum, dens in dente, dilated composite odontome, warty tooth, dents télescopées, gestant anomaly, odontopagus parasiticus incretus, dens invaginatus, dilated gestant odontoma, tooth inclusion and dentoid in dente. An attempt to classify DI was first proposed by Hallett [1953]. The first three types of DI in Hallett’s classification refer to crown invaginations. However, all crown invaginations were designated as type 1 in a classification system put forward by Oehler [Oehler, 1957a, Oehler, 1957b]. Other classifications have also been described by Ulmansky and Hermel [1964], Schulze and Brand [1972a, 1972b, 1972c] Vincent-Townend [1974], Parnell and Wilcox [1978], Hicks and Flaitz [1985]. The broad classification put forward by Schulze and Brand (1972) includes 12 variations of DI starting at the incisal edge of teeth and therefore classifies malformations with respect to morphology of the invagination as well as the anatomic crown form and dysmorphic root configurations [Hulsmann, 1997; Hulsmann and Hengen, 1996]. However, the system described by Oehler (1957a) appears to be the most widely used, possibly because of its simple nomenclature and ease of application [Alani and Bishop, 2008].

The invagination varies in size and shape from a small dip in the enamel to a severe form, which looks like a tooth within a tooth. The invagination frequently communicates with the oral cavity, allowing the entry of irritants and microorganisms either directly into the pulp tissues or into an area that is separated from pulp tissues by only a thin layer of enamel and dentin [Ruprecht et al., 1987]. This continuous penetration of irritants and the subsequent inflammation usually lead to necrosis of the adjacent pulp tissue and then to periapical or periodontal abscesses [Hulsmann and Hengen, 1996; Ruprecht et al., 1987].

Several clinical, radiographic and histologic attempts have been made for a better understanding of the morphology of the invagination and its association with pulp disease. Visual examination with or without the aid of magnification, plain two-dimensional radiographs, dye indicators (such as methylene blue) and Cone Beam Computerized Tomography (CBCT) are documented in vivo techniques. Histological sections, chemical analyses,
Scanning Electron Microscopy (SEM), microradiography, micro X-ray diffraction, micro Computerized Tomography (μCT) and Magnetic Resonance Imaging (MRI) are few available options for extracted DI teeth.

Conventional two-dimensional radiographs do not provide enough structural information about the malformation. CBCT is a three-dimensional imaging technique which has a reduced radiation dose in comparison to CT and overcomes the limitations of conventional radiography by providing more structural information [Patel and Dawood, 2007]. Magnetic resonance imaging (MRI) is a non-invasive imaging modality which does not use any ionizing radiation to simultaneously image calcified and non-calcified dental tissues [Idiyatullin et al., 2011]. High resolution micro CT is an emerging non-destructive technology that aids in precise and highly accurate in vitro evaluation [Zogheib et al., 2012].

The objective of this study was threefold.
1. To perform an in vitro radiographic analysis of three extracted DI teeth with complex root anatomy by comparing plain radiographs, CBCT, MRI and micro CT images.
2. To classify the three teeth based on the morphology of the invagination.
3. To examine the relationship of the invagination to the oral cavity and its proximity to the pulp tissue.

**Materials and methods**

**Study design**

Three maxillary lateral incisor teeth from two patients were extracted due to infection complications associated with DI and were radiographically analysed. Initially, four conventional two-dimensional digital radiographs were made, aiming from labial, palatal, mesial and distal surfaces. Subsequently CBCT, micro CT and MRI analyses were performed after fixing the tooth to a wax block.

The first tooth under investigation was a right maxillary lateral incisor (FDI notation 12) of a 9-year-old patient that was extracted due to complex anatomy of the invagination and poor prognosis. The second and the third teeth belonged to a 10-year-old orthodontic patient who presented with DI bilaterally with respect to maxillary lateral incisors (FDI notation 12 and 22). For practical purposes, they shall henceforth be referred to as tooth A, B and C respectively.

All teeth were exposed to the above mentioned imaging techniques. The exposure parameters and other specifications for each technique are summarised in Table 1. The teeth were cleaned and stored in water as it was necessary to prevent them from dehydrating before the MRI imaging could be performed. All images were viewed on a 55" LED screen by two authors (S.R and J.A) in a darkened room. The conventional radiographs, the CBCT images and the DICOM images of micro CT and MRI were analysed using Mediadent™, Planmeca Romexis Viewer™ and Osirix™ software respectively.

**Results**

At first, the three teeth were analysed with the conventional plain two-dimensional radiographs, as shown in figure 1.

The three teeth had open apices and three different forms of invaginations were clearly visible. According
to Oehler’s classification system, tooth A and tooth B could not be classified whereas tooth C was classified as type II. According to the Schulze and Brand system of classification, teeth A, B and C were classified as A2, B3 and B2 respectively. The break of enamel lining at the incisal edge, which could be responsible for the penetration of irritants, is not visible in tooth A while it is faintly visible in the incisal region in tooth B and C. The proximity of the invagination to the pulp tissue could not be evaluated using these radiographs.

Following the plain two-dimensional digital radiographs, CBCT images (Fig. 2a-2c, Fig. 3a-3c) were obtained.

From the CBCT images, the abnormal morphology of tooth A at the cingulum was visible (Fig. 2a[1]). Moreover, the invagination was clearly visible from the root end view (Fig. 2a-4). Figure 2b-1-4 showed that the crown was conically shaped and the root was

![FIG. 2A CBCT images showing the external appearance of tooth A.](image)

![FIG. 2B CBCT images showing the external appearance of tooth B.](image)

![FIG. 2C CBCT images showing the external appearance of tooth C.](image)

![FIG. 3A CBCT images of the coronal and sagittal slices of tooth A.](image)

![FIG. 3A CBCT images of the coronal and sagittal slices of tooth B.](image)

![FIG. 3C CBCT images of the coronal and sagittal slices of tooth C.](image)

![FIG. 4A MRI images of the coronal and sagittal slices of tooth A.](image)

![FIG. 4B MRI images of the coronal and sagittal slices of tooth A.](image)

![FIG. 4C MRI images of the coronal and sagittal slices of tooth C.](image)
bulbous. The same crown morphology was seen for tooth C (Fig. 2c-1-4), but the root morphology showed a distal curvature starting from the middle third of the root length (Fig. 2c-2,4).

For tooth A, CBCT images indicate the path of invagination defined by the enamel lining (Fig. 3a-5). In tooth B, the enamel lining of the invagination is very thin and non-continuous. The apex of the invagination appears to be closed (Fig. 3b-5). In tooth C, the enamel lining of the invagination is broken and mostly absent. The invagination is more towards the mesial wall of the root surface, further away from the root curvature (Fig. 3c-3).

In the MRI analysis, the invagination of tooth A is continuous from the coronal to the apical portion in spite of the constriction seen at the apical third of the invagination (Fig. 4a-5), whilst in tooth B neither the invagination nor the pulp chamber appears to have a continuous lumen as could be seen in figure 4b-3,4,5. The lumen of the invagination is broad and cocoon-shaped in tooth C (Fig. 4c-3,4).

From the micro CT images of tooth A, B and C, the point of entry of irritants into the lumen of the invagination is visible (Fig. 5a-6, 5b-5 and 5c-2 respectively). The complexity of the invagination of tooth A is apparent in the axial slices (Fig. 5a-10). In tooth B, an enamel lined constriction in the middle of the invagination is seen (Fig. 5b-3,6) and the apex of the invagination appeared to be closed (Fig. 5b-1,2). In tooth C, non-continuous enamel lining along the walls of the invagination could be observed (Fig. 5c-3,6).

Discussion

In the present report of three maxillary lateral incisors, two bilateral teeth were analysed. According to the literature, the teeth most commonly affected with DI are the maxillary lateral incisors [Cakici et al., 2010]. Bilateral occurrence with a prevalence of 43% was first reported by Swanson and McCarthy in 1947 [Swanson and Mc, 1947].

The morphology of the crown of a DI tooth can either be normal or abnormally shaped. Frequently reported variations include peg-shaped, conical, talon cusp, shovel-shaped and barrel shape [Ridell et al., 2001]. Within the teeth examined here, tooth A had normal crown morphology whereas the crown was conically shaped in teeth B and C. The abnormal shape of a crown can occasionally be a hint in diagnosing DI.

In 1887, Tomes quoted in his textbook “A System of Dental Surgery” that: «If the section be a fortunate one, we shall be able to trace the enamel as it is continued from the exterior of the tooth through the orifice into the cavity, the surface of which is lined more or less completely with this tissue» [Hulsmann, 1997]. Since then we have come a long way in imaging including non-destructive techniques to obtain numerous high precision images of thin slices of a single tooth from all possible surfaces.

Classification systems are helpful for the purpose of categorisation, communication and identification of treatment needs. The classification system by Oehlers (1957) has a very simple nomenclature, but it does not help classify certain rare variants which could be identified according to Schulze and Brand (1972). Both classification systems were based on two-dimensional analogue radiographs and series of longitudinal sections of decalcified teeth. The vast amount of information, such as the point of communication and the path of invagination that could be obtained from
three-dimensional imaging, is evident in the present report.

The point of communication of the invagination to the oral cavity is clinically significant with respect to the preventive treatment that aims in sealing the entry of irritants into the invagination [Kaneko et al., 2011]. It is also important in determining the access point in case an endodontic treatment is intended [Patel, 2010a].

Only micro-CT could determine the point of entry of irritants in all the three teeth presented while the other radiographic techniques only indicated a faint radiolucency implying the possible location of the entry to the invagination. The latter could be better determined after viewing the micro-CT images first.

In a DI tooth, the “inner” enamel is continuous with the outer enamel at and through the lingual pit. In a cross section from outside inwards, the typical sequence of enamel, dentin, space (= pulp), dentin, enamel was reported by Wustrow [Kronfeld, 1934]. This holds true in all the three teeth discussed and is visible in the sagittal, coronal and axial sections of CBCT, MRI and micro-CT images. This sort of a qualitative differentiation of the layers of the invaginated tooth is almost impossible from clinical two-dimensional radiographs.

The infection could also result from a communication between the invagination cavity and the pulp due to the presence of channels or incomplete enamel lining [Kramer, 1953]. The knowledge of the communication between the pulp and the lumen is relevant from the treatment point of view as it determines whether or not to endodontically treat the pulp chamber [Durack and Patel, 2011]. There have been reported cases where successful treatment has been achieved by exclusively treating the invagination [Patel, 2010a; Kfir et al., 2013]. In tooth A the invagination is completely lined by a thick layer of enamel resulting in complete exclusion of the pulp chamber from the irritants. In tooth B and tooth C, the enamel lining of the invagination was discontinuous, thereby increasing the chance of communication between the invagination and the pulp chamber through the presence of dentinal tubules [Crincoli et al., 2010].

In contrast to other radiographic techniques that are based on the mineral content of the tissue, MRI imaging is based on the water content of the tissue under investigation [Matteson et al., 1996]. This principle makes it suitable for imaging sinuses, tumour staging, temporomandibular joints, periapical pathosis and salivary glands, but it could also be used to read tooth structure as enamel and dentin contain water in varying amounts. The present report is the first study evaluating hard tissue of a tooth structure using MRI as a viable option and apparently MRI is specifically advantageous in DI teeth as the lumen of the invagination and pulp chamber can be sufficiently traced. Interpretation and analysis of the MRI image may be difficult and require adequate practice, but it should definitely be considered as an alternative imaging technique due to zero radiation exposure.

Currently, MRI and micro CT techniques are not an option in vivo, nevertheless for extracted teeth sufficient details can be obtained. MRI imaging for teeth is a promising option and could be available in the near future. At present, CBCT is the best possible choice of radiographic imaging available in vivo and provides a three dimensional image that leaves very little to the imagination of the dentist. Care must be taken to prescribe the smallest Field of View (FOV) possible and abide by the ALARA principle while using CBCT for DI teeth, especially in children [Patel, 2010b].

Conclusion

Reporting on these three DI teeth, it is clearly shown that normal conventional radiographs do not provide detailed structural information about this malformation due to geometric distortion and lack of information about the third dimension. MRI analysis was complementary to the CBCT analysis and MRI being non-invasive could be a useful alternative to CBCT, considering the radiation dose of CBCT. While micro-CT analysis revealed detailed structural and morphological information, it cannot be used in vivo owing to the high radiation exposure.

The advent of new, high resolution and three dimensional radiographic techniques call for a revised and extensive classification system, which could help increase accuracy of diagnosis and ease of determining treatment need even in rare variants.

Conventional two-dimensional radiographs were of little help in detecting the point of entry of the irritants from the oral cavity into the invagination. In tooth B and C, CBCT could neither reveal the point of contact of the invagination with the oral cavity nor diagnose the proximity of the invagination to the pulp chamber, whereas it was very clearly visible in micro-CT analysis.

References


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