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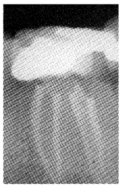

CLINICAL ARTICLE

Dens invaginatus. Part 2: clinical, radiographic features and management options

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Abstract

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Aim To describe the possible clinical and radiographic features of this developmental anomaly, review previous treatment recommendations and suggest management options based on the classification of the problem.

Summary This paper describes the clinical and radiographic features related to the different types of dens invaginatus and highlights those features which may indicate the presence of a previously undetected invagination. Aids to clinical diagnosis are described together with a description of the possible radiographic features, which may suggest the presence of an invagination. Previous treatment suggestions are described and suggestions as to possible management options, based on current endodontic knowledge and the classification of the problems are described.

Key learning points

• Thorough clinical and radiographic examination is required to diagnose and successfully treat minor to severe invaginations.

• Modern clinical techniques may facilitate the management of invaginations once considered untreatable.

Keywords: dens in dente, dens invaginatus, microscopy, mineral trioxide aggregate, root canal treatment.

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Introduction

In the first paper, the prevalence, classification and aetiology of dens invaginatus was discussed. In this second of the series, the possible clinical presentations of the problem will be highlighted and the treatment options considered.

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Clinical presentation

In deciduous teeth, there have only been a limited number of well-documented case reports (Table 1), one of which described an invagination located on the incisal edge of the tooth. This is in contrast to permanent incisors and other anterior teeth where the entrance to the defect invariably begins palatally.

Although there appears to be consistency where the invagination is located in the permanent dentition there can be a great variation in other clinical features. For example, the invagination may be barely noticeable with the only indication being a slightly exaggerated cingulum pit. In contrast, the lesion may be substantial with a deep infolding reaching the apical foramen (Pindborg 1970). There may also be associated grooving of the palatal enamel, coincident with the entrance of the invagination (Fig. 1). The enamel within the groove has been described as hypoplastic (de Sousa & Bramante 1998) although this observation has not been supported by any histological evidence (Fig. 2).

Often the entrance to the invagination is difficult to locate and as such the use of magnification can aid identification and has also been advocated if root canal treatment becomes necessary (Girsch & McClammy 2002). The application of methylene blue dye to the palatal portion of the tooth can also be useful (Fig. 1) as can radiopaque markers. The latter can also help illustrate the extent and shape of the invagination.

Although the morphology of the tooth itself may appear normal (Gonçalves *et al.* 2002) the following changes in the shape of a tooth affected by dens invaginatus have also been described:

- increased labio-lingual or mesio-distal diameter (Khabbaz *et al.* 1995, de Sousa & Bramante 1998, Girsch & McClammy 2002);
- incisal notching in association with a labial groove (Khabbaz *et al.* 1995) (Fig. 3);

Table 1 Reported cases of dens invaginatus affecting the primary dentition

Author and year	Age	Gender	Tooth affected	Pulpal complications	Treatment
Rabinowitch 1952	3	M	Maxillary canine	Yes	Extraction
Holan 1998	5	M	Mandibular canine	Yes	Root canal therapy
Kupietzky 2000	1	M	Maxillary central incisor	No	Tooth coloured restoration
Eden *et al.* 2002	11	M	Mandibular second molar	Yes	Extraction

Figure 1 Palatal view of a maxillary lateral incisor illustrating deep grooving leading to the entrance of the invagination. Methylene blue dye has been used to illustrate the extent and aid in identification.

Figure 2 Palatal view of an invaginated maxillary lateral incisor with a hypoplastic appearance associated with the entrance to the invagination.

Figure 3 An invaginated maxillary lateral incisor, with notching of the incisal edge and associated buccal grooving.

Figure 4 Bilateral dens invaginatus of the maxillary lateral incisors with exaggerated palatal cingula/talon cusps.

- a peg or conical morphology (Oehlers 1957a);
- the presence of an exaggerated palatal cingulum or 'talon cusp' (Oehlers 1957a) (Fig. 4).

Ridell *et al.* (2001) reported that in 91 patients with dens invaginatus, 16% of affected teeth had a peg or conical shape and 9% had evidence of talon cusps. In the authors' experience, a bifid cingulum can also be associated with the presence of dens invaginatus although this feature appears not to have been reported previously (Fig. 5a,b).

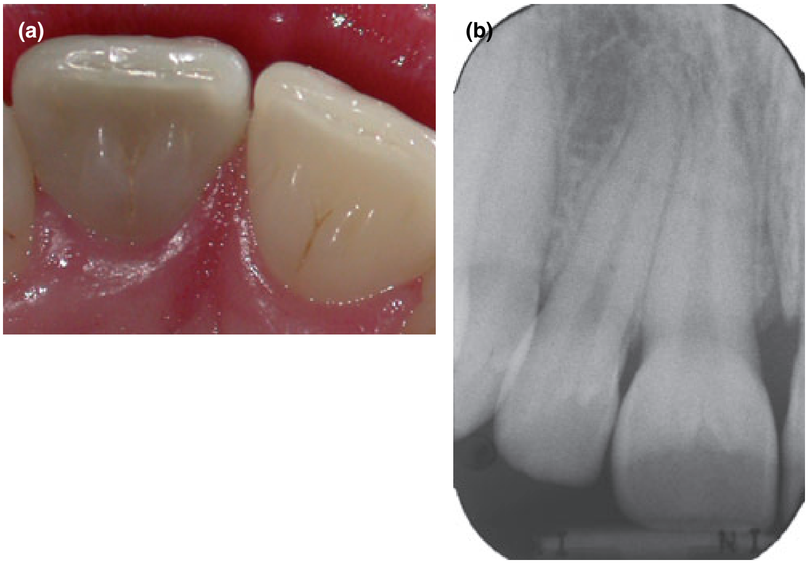

Figure 5 (a) Maxillary central incisors affected by dens invaginatus. Note the bifid cingulum associated with both central incisors and the discolouration of the upper right central incisor. (b) An intraoral radiograph demonstrating the presence of Oehlers type I dens invaginatus and the bifid cingula.

In addition, patients with evidence of dens invaginatus may also have other dental anomalies, malformations and syndromes (Table 2). For this reason, it may be useful to consider the possible presence of an invagination when abnormal tooth morphology is observed. Similarly, as a symmetrical pattern has also been reported, both clinical and radiographic examination of the contra-lateral tooth may be advisable when dens invaginatus has been identified on one side (Grahnen *et al.* 1959) (Fig. 4).

The affected tooth may also show or have a history of the signs and symptoms traditionally associated with pulpal disease (Oehlers 1957b, Omnell *et al.* 1960, Beynon 1982, De Smit *et al.* 1984, Rotstein *et al.* 1987, Ridell *et al.* 2001). For this reason, in teeth with no other obvious cause for pulp disease, the presence of an invagination should be considered, particularly if other features associated with the anomaly are present (Seow 2003).

Radiographic image

The use of radiographs to aid in the diagnosis of dens invaginatus is influenced by a number of factors. These include the quality of the radiograph, the clinician's knowledge and experience as well as their three-dimensional awareness of how the problem can present (Tagger 1977). The angulation of the film is particularly important because the presence of an invagination may not be apparent on standard parallel views (Fig. 6a,b). As such, it may be advisable when an invagination is suspected to obtain a second radiograph with a 15° change in the horizontal angulation of the beam and the tube more mesially placed.

The radiographic image may include:

1. The shape of the invagination varying from a narrow and undilated fissure (Fig. 5) to a tear-shaped loop pointing towards the main body of the pulp (Parnell & Wilcox 1978, Gotoh *et al.* 1979) (Fig. 7).

Table 2 Studies reporting dental anomalies and syndromes in association with dens invaginatus

Anomaly	Study
Microdontia	Casamassimo *et al.* 1978, Mupparapu & Singer 2006
Macrodontia	Ekman-Westborg & Julin 1974
Hypodontia	Hülsmann 1995a,b
Oligodontia	Conklin 1978, Ruprecht *et al.* 1986
Taurodontism	Casamassimo *et al.* 1978, Ruprecht *et al.* 1986, Ireland *et al.* 1987, Chen *et al.* 1990
Gemination and fusion	Burzynski 1973, Mader 1979, Mader & Zielke 1982, Ruprecht *et al.* 1986, Pereira *et al.* 2000, Canger *et al.* 2007
Supernumerary teeth	Schaefer 1953, 1955, Brabant & Klees 1956, Petz 1956, Rushton 1958, Conklin 1975, Mader 1977, Shifman & Tamir 1979, Beynon 1982, Ruprecht *et al.* 1986, Morfis 1993, de Sousa & Bramante 1998, Jimenez-Rubio *et al.* 1997
Dentinogenesis imperfecta	Kerebel *et al.* 1983
Invagination in an odontome	Hitchin & McHugh 1954
Multiple odontomes	Robbins & Keene 1964
Coronal agenesis	Hicks & Flaitz 1985
Shovel-shaped incisors	Saini *et al.* 1990
Williams syndrome	Oncag *et al.* 1995
Mesiodens	Sannomiya *et al.* 2007
Obliterated pulp chambers	Desai *et al.* 2006
Dens evaginatus	Mupparapu *et al.* 2004
Nance Huran syndrome	Hibbert 2005
Talon cusp	de Sousa *et al.* 1999
C-shaped canal configuration	Bóveda *et al.* 1999
Palatogingival groove defect	Yeh *et al.* 1999
Short root anomaly	Desai *et al.* 2006
Peg-shaped/shovel-shaped	Oehlers 1957a
Dilaceration	Gound & Maixner 2004
Albinism	Suprabha 2005
Periodontal abscess	Chen *et al.* 1990
Multiple root canals	Jung 2004
Cranial suture syndromes	De Coster *et al.* 2007
Unicystic ameloblastoma	Paikkatt *et al.* 2007
Coronal fractures	Caldari *et al.* 2006
Ekman–Westborg–Julin syndrome	Mann *et al.* 1990

2. The appearance of the invagination as a radiolucent pocket surrounded by a radio-opaque enamel border (White & Pharoah 2000). The pocket may vary in distance from the incisal edge and proximity to the dental pulp (Fig. 7) although the presence of this radiopaque border may not always be apparent (Fig. 8).

3. The pulpal morphology appearing more complex than normal and difficult to delineate from the root canal (Fig. 9).

4. The invagination being completely separate from the pulp and manifest as a deep enamel-lined fissure with its own opening into the periodontal ligament. This has also been described as a 'pseudo-canal' (Gonçalves *et al.* 2002) (Fig. 9).

5. The associated lesion may be extensive with abnormal form and shape (Figs 8 and 9).

6. An alteration in the pulpal outline when in proximity to the invagination. For example, there may an abrupt change in the border of the pulp chamber or blunting of the pulp horns in anterior teeth (Figs 8 and 10).

If loss of vitality occurs soon after eruption then further root development may cease, which may be radiographically apparent with time. However, the early radiographic identification of dens invaginatus in a developing tooth can be difficult (Swanson &

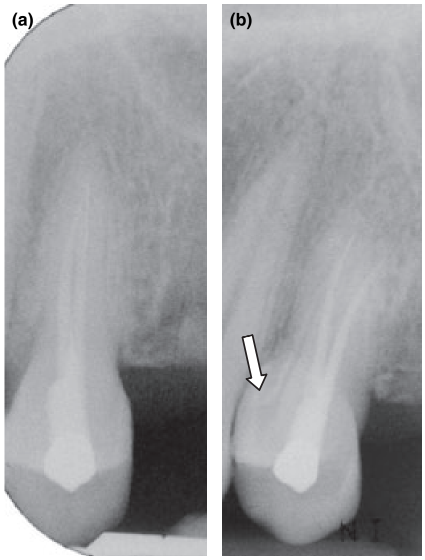

Figure 6 (a) An intraoral radiograph of a maxillary first premolar which had recently been root canal treated during which an instrument had separated. The patient had continued problems. (b) A view with mesial angulation confirming the presence of a separated instrument and the presence of the previously unidentified dens invaginatus (white arrow).

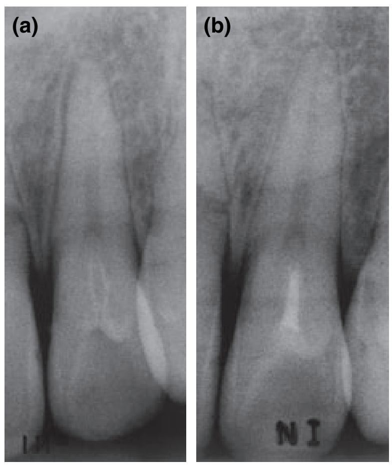

Figure 7 Intraoral radiographs of a maxillary lateral incisor with Oehlers' type II dens invaginatus. Pre- (a) and post- (b) prophylactic treatment with MTA and composite. Note the tear-shaped loop of the invagination.

McCarthy 1947, Ulmansky & Hermel 1964, Stepanik 1968, Ferguson *et al*. 1980, Morfis & Lentzari 1989, Hülsmann & Radlanski 1994, Nik-Hussein 1994) and the implications associated with pulp disease in an immature tooth may be unavoidable (Fig. 10).

Treatment options

Until the 1970s, teeth affected by dens invaginatus were considered to have a poor prognosis and extraction was advocated as the treatment of choice (Dechaume 1966). This may still be the correct option in some cases, particularly teeth with severe

Figure 8 An intraoral radiograph of a nonvital mandibular premolar with dens invaginatus. Note the blunting of the pulpal outline, the associated atypical butterfly-shaped apical radiolucency.

invaginations (Rotstein *et al.* 1987, Rakes *et al.* 1988, Hülsmann 1995b, de Sousa & Bramante 1998, Seow 2003, Pandey & Pandey 2005, Stamfelj *et al.* 2007).

However, with a greater understanding of the morphology of the invagination and its association with pulp disease, preventive procedures to seal minimal invaginations have been recommended. These have involved varying degrees of intervention (Parnell & Wilcox 1978, De Smit & Demaut 1982, Rotstein *et al.* 1987, Szajkis & Kaufman 1993, Hülsmann 1995b, Hosey & Bedi 1996).

For example, a number of authors have advocated an invasive prophylactic approach in the treatment of Oehlers' type II lesions. This has involved coronal instrumentation of the invagination and subsequent filling with amalgam (Holtzman 1998, de Sousa & Bramante 1998) or gutta-percha (Tsurumachi *et al.* 2002). An alternative technique described by Ridell *et al.* (2001) involved filling with calcium hydroxide and zinc-oxide/eugenol together with either glass–ionomer cement, composite or amalgam. Unfortunately, 11.3% of the teeth treated in this study developed irreversible pulpal complications requiring root canal treatment or extraction. This outcome may reflect the difficulty in dealing with the aberrant anatomy present within the invagination.

If an invaginated tooth develops pulp disease or has a high risk of doing so, the need for root canal treatment is unavoidable if extraction is not an option. Grossman (1974) and Creaven (1975) were the first to describe the use of conventional endodontic techniques and materials in the treatment of severely invaginated teeth. Unfortunately, such an

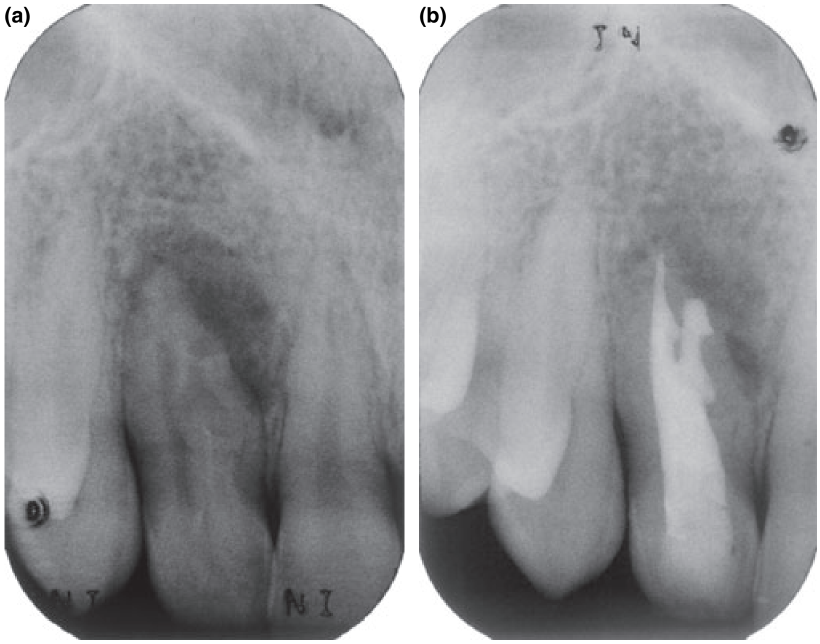

Figure 9 (a) Pre-op intraoral radiograph of a maxillary lateral incisor with Oehlers' type III dens invaginatus. Note the 'blunderbuss' opening of the invagination into the periodontal ligament and the atypical shape of the radiolucency associated with this nonvital tooth. (b) Post-treatment. The canal was obturated with thermoplastic gutta-percha and the invagination filled with MTA.

approach is often not straightforward with Tagger (1977) and Holtzman & Lezion (1996) describing the difficulties involved in teeth with type III invaginations. Both authors highlighted the particular problems associated with achieving adequate chemomechanical debridement of the root canal system and invagination, predictable length control and consistent filling. The presence of an enamel lining to the lumen of the invagination, the invariable aberrant anatomy and the absence of a true apical constriction if the invagination opens into the periodontal ligament all contribute to make successful cleaning, shaping and filling difficult. In the case of the latter, the opening often has a funnel or 'blunderbuss' shape similar to that found in immature or resorbed apices (Fig. 9).

Despite these limiting factors, a number of authors have described successful preparation of type III invaginations using hand files and sodium hypochlorite irrigation (Khabbaz *et al.* 1995, Schwartz & Schindler 1996, Pitt Ford 1998, Tsurumachi *et al.* 2002, Tsurumachi 2004, Er *et al.* 2007) whilst the use of passive ultrasonic energy has also been advocated (Skoner & Wallace 1994). Successful obturation of the invagination has also been achieved with gutta-percha (Khabbaz *et al.* 1995, Pitt Ford 1998, Gonçalves *et al.* 2002, Gound & Maixner 2004, Nallapati 2004).

Although treatment of an infected invagination appears possible, the question arises as to whether it is always necessary to devitalize an adjacent healthy pulp as part of the therapy. In addition, if both the root canal and the invagination require treatment, a decision has to be made whether this is achieved with the lesion remaining separate to the root canal system or incorporated into it.

A number of techniques have been described to manage type III lesions where the pulp remains healthy but the invagination is associated with a periodontitis.

One option, which has been associated with a favourable outcome, is to limit the treatment to the invagination using conventional endodontic techniques (Szajkis &

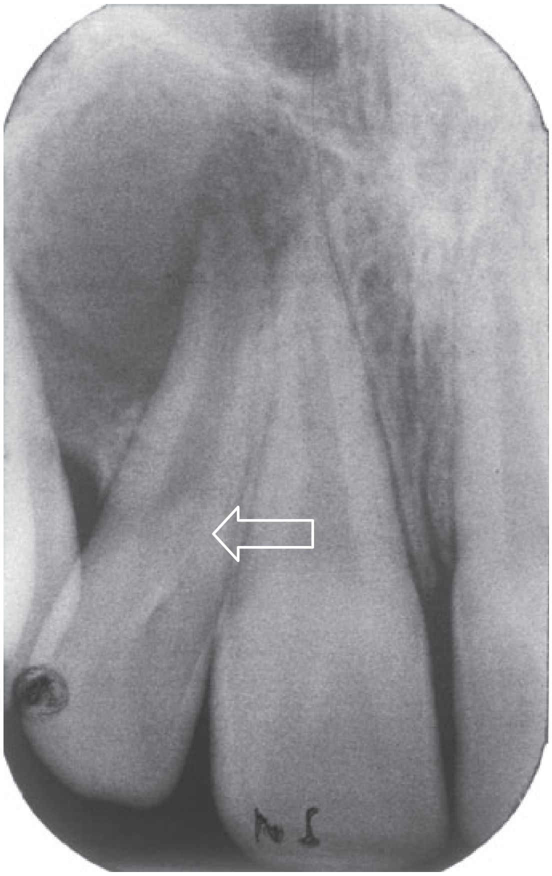

Figure 10 An intraoral radiograph of a nonvital immature maxillary lateral incisor with dens invaginatus type I. Note the blunting of the pulp chamber outline (white arrow).

Kaufman 1993, Schwartz & Schindler 1996, Fristad & Molven 1998, Pitt Ford 1998, Gonçalves *et al.* 2002, Gound & Maixner 2004, Tsurumachi 2004). However, this can only be a consideration when the invagination is clearly separated from the root canal both prior and subsequent to preparation.

Nallapati (2004) described a similar approach but in this case a surgical regime was adopted with a root-end filling placed where the invagination opened into the periodontal ligament. Resection of a portion of the invagination was also carried out to aid access and visualization. In this situation, the health of the pulp was preserved but orthograde treatment of the invagination was also planned and subsequently carried out. The authors only reported a 4-month follow-up period but there was evidence of periodontal healing radiographically and persistent positive responses to pulp sensibility testing.

In contrast, Chen *et al.* (1998) considered that only treating the infected invagination was not sufficient. They found that it was also necessary to treat the pulp even if it was apparently still healthy. This finding may reflect the close inter-relationship and possible communication between severe invaginations and the main root canal system even when radiographically they appear distinct.

Thus, it would appear possible to treat an infected invagination in isolation of a healthy pulp but close follow-up and monitoring is essential. If resolution does not occur, then consideration may need to be given to root canal treatment.

When both the invagination and root canal require treatment, consideration again has to be given as to whether, they are treated separately or their anatomy is combined.

Hovland & Block (1977) were the first to describe the use of conventional endodontic methods to treat both the infected invagination and a necrotic pulp separately. This approach has subsequently been described by other authors (Khabbaz *et al.* 1995, Yeh *et al.* 1999, Tsurumachi *et al.* 2002, Pai *et al.* 2004) with radiographic signs of positive periodontal healing recorded at a minimum of 6 months postoperatively.

In contrast, two more recent reports (Girsch & McClammy 2002, Silberman *et al.* 2006) describe, as the objective at the outset, the complete removal of an invagination to create one large canal space in type III invaginations. This was achieved using both ultrasonic instrumentation and magnification to create a more predictable root canal for cleaning and subsequent filling in teeth with extreme forms of dens invaginatus. The healing of the cases was favourable although large amounts of tooth tissue were removed.

In contrast, similar lesions to those described by Silberman *et al.* (2006) and Girsch & McClammy (2002) were treated successfully using conventional endodontic techniques but without gross modification of the internal anatomy (Pai *et al.* 2004, Kremeier *et al.* 2007). This would suggest that modern endodontic methods may not automatically necessitate the combining of the root canal and invagination during treatment. This obviously has the advantage of conserving tooth tissue.

In type III lesions, extraction, endodontic treatment in combination with intentional reimplantation has also been described with favourable short-term results (Lindner *et al.* 1995, Nedley & Powers 1997).

A surgical approach has also been advocated to treat the root canal and invagination either alone (Kulild & Weller 1989, de Sousa & Bramante 1998), after conventional treatment has failed (Hata & Toda 1987, Kulild & Weller 1989, Benenati 1994) or combined with an orthograde root filling provided at the same time (da Silva Neto *et al.* 2005). In a single case, Bolanos *et al.* 1988 used apical curettage rather than an apical resection in conjunction with orthograde treatment to treat an invaginated type III tooth and reported favourable 5-year results. Considering the current concepts in endodontics and the apparent success associated with a conventional approach to dealing with invaginated teeth, it would seem reasonable to consider a surgical approach only when conventional treatment is associated with post-treatment disease.

In the case of immature invaginated teeth with necrotic pulps, traditional apexification techniques using calcium hydroxide have been described (Morfis & Lentzari 1989, Holtzman & Lezion 1996). The use of mineral trioxide aggregate (MTA) to achieve an apical barrier has also been reported (Sübay & Kayataş 2006, Sathorn & Parashos 2007). In contrast, Schindler & Walker (1983) reported situations where continued root development occurred in the presence of gutta-percha rather than calcium hydroxide or MTA. Surgical treatment of an invaginated immature tooth with a necrotic pulp has also been described (Rotstein *et al.* 1987). In these cases, the invagination was either incorporated into the root canal or, if easily negotiated, cleaned and filled separately.

It would therefore appear that there are a range of options available to manage a tooth affected by dens invaginatus. The options are even wider when the potential benefit of modern techniques and materials such as microscopy (Carr 1992), ultrasonic instrumentation (Skoner & Wallace 1994) and MTA (Gaitonde & Bishop 2007) are also considered. However, it would appear that a reasonable approach to the initial management of invaginated teeth with healthy pulps should be to prevent pulpal problems developing and conserve tooth tissue. As such, initially the teeth should be clinically assessed, the pulp vitality evaluated and depending on the pulpal status, radiographic degree of root development and the extent of the invagination, an appropriate treatment regime instigated.

Treatment recommendations

When any restorative procedure is considered, the benefit of maintaining the tooth has to be balanced against the predictability of the treatment planned whilst also bearing in mind the general condition of the mouth and possible future treatment needs. This is particularly the case where severe invaginations are present. Extraction of the tooth will result in a predictable and acceptable result; this may be the preferred option especially in young patients where orthodontic treatment may be required irrespective of the presence of an invaginated tooth. However, if the objective is to attempt to retain an invaginated tooth then the following treatment regimes may be considered:

Minimal invaginations (Oehlers' type I)

In situations where the invagination is restricted to the crown of the tooth and there is no evidence of pulpal disease, prophylactic treatment should be instigated as soon as predictable moisture control can be achieved. This is particularly important in teeth with immature root development as the repercussions of pulp disease can be difficult to manage (Gaitonde & Bishop 2007).

Acid-etched fissure sealant or flowable composite resin material can be used to seal the entrance to the invagination. Where an entrance is not clinically detectable but a minimal invagination is present radiographically the same regime should be followed because the defect may still be a portal for bacterial contamination. The teeth should then be monitored regularly for possible pulp disease or deterioration of the restoration.

If pulpal disease is present or subsequently develops, root canal treatment can be instigated. It is probably that the root canal morphology of type I will be uncomplicated other than in the area adjacent to the invagination. In situations where it is considered that the inflammation is limited, particularly in immature teeth, a vital pulpotomy could be considered. If the disease is more extensive, a more conventional approach should be considered. The only additional consideration is to ensure adequate debridement and cleaning of the invagination. To achieve this, the lesion should be incorporated into the access by simply extending the cavity and initial instrumentation of the root canal system. Gates Glidden burs or ultrasonic alloy tips of an appropriate size used in a light upwards brushing motion are particularly useful for this purpose. The area should then be directly and carefully examined, preferably under magnification, to ensure that the invagination is completely cleaned and blends into the access cavity. A probe can also be used to ensure the absence of any ledging or hard tissue pocketing. Canal filling is best achieved using thermoplastic gutta-percha and the access restored using glass–ionomer or a flowable composite material overlaid with an acid-etched traditional composite.

Moderate invagination (Oehlers' type II)

Because of the increased extent of the invagination, in these cases prophylactic sealing of the entrance of the invagination in teeth with healthy pulps could result in a substantial void or dead space. In addition, as direct visualization of the whole of the invagination may not be possible, there is also a possibility that caries may go undetected. For this reason, it may be more appropriate to prepare a coronal entrance to successfully inspect, prepare, fill and seal the invagination.

Access can be achieved using a tungsten carbide bur and magnification used to inspect the invagination. If caries is present, then this can be removed using long-necked round burs or ultrasonic tips. Once access is gained, the use of ultrasonic alloy tips can be used to aid debridement of the invagination. The lumen should be cleaned and irrigated with chlorhexidine or 1% sodium hypochlorite prior to the invagination being filled and sealed. The use of ultrasonics will also supplement chemical decontamination of the invagination.

As it is impossible to exclude the possibility of a pulpal communication, even under magnification, it would seem sensible to treat all such invaginations as directly involving the pulp. As such the cavity after cleaning should be managed in the same manner as a direct pulpal exposure. Considering the properties of MTA, it would seem that this material would be the one of choice in such circumstances. Vertical compaction of MTA into the lumen can be achieved, following the removal of excess moisture, using standard endodontic pluggers of appropriate size. A coronal seal can then be obtained by placing an acid-etched composite restoration into the access cavity (Fig. 7).

If an obvious communication with the pulp is apparent or caries is extensive then either a pulpotomy or extirpation of the pulp and subsequent endodontic treatment could be considered in a similar way to necrotic pulps with Oehlers' type I lesions. The only difference lies in the fact that type II invaginations are invariably wider and extend further apically (Oehlers 1957a). As a result, care should be taken to ensure that the lesion is fully exposed when achieving access and the lesion is fully incorporated into the root canal system during preparation (Fig. 11).

Severe invagination (Oehlers' type III)

In these more complex and extensive lesions, if there is no evidence of pulp disease or the invagination does not appear to be affected by caries or is retaining plaque, then initially a simple prophylactic approach should be adopted similar to that previously described for type I lesions. The health of the pulp should then be monitored closely both clinically and radiographically.

A more aggressive prophylactic approach in the treatment of this type of invagination could result in a frank pulpal exposure or, as a result of its extent, failure to clean and fill the lesion adequately. Furthermore, because of the invariably complex root canal morphology associated with this type of lesion, the risk of post-treatment disease increases.

Figure 11 (a) An intraoral radiograph of a nonvital lateral incisor with dens invaginatus. (b) After the extirpation of the pulp, the clinician failed to include the invagination into the access cavity.

Where a 'peri-invagination periodontitis' exists and the pulp remains healthy all efforts should be aimed at preserving pulp health. As such, the objective should be to treat the invagination in isolation to the root canal. In practical terms, this may only be potentially possible with Oehlers type III A lesions because of the proximity apically of the invagination and the root canal in type III B invaginations.

The use of microscopy and methylene blue dye can aid the identification of the opening of the invagination and assist in subsequent instrumentation. Once access is gained, a radiographic marker such as a gutta-percha point or endodontic file, can be placed within the lesion to ensure correct orientation.

The invagination can then be cleaned and shaped along the lines described for type II lesions, although the use of rotary instrumentation within the lesion is not recommended. This is based on the fact that the surface is predominantly covered in enamel and has an inconsistent shape which may increase the likelihood of instrument fracture. As such, ultrasonic alloy tips may be more useful than stainless steel or nickel titanium endodontic instruments.

In situations where the pulp is necrotic, it may be possible to treat the canal and invagination separately. However, in practice, the proximity of the root canal to the invagination and the complex and invariable interconnections between them means that it is almost inevitable that they will need to be combined.

This can be achieved with the use of ultrasonic instruments or long-shanked round burs working from the root canal side of the divide between the root canal and the invagination. The apical region of the root canal can be prepared using conventional endodontic techniques. Care should be taken in this area because it is probably that joining the invagination with the root canal would result in destruction of any apical constriction. As such, in this region, the invagination and root canal may still be better kept separate.

Once preparation is completed, filling with gutta-percha is acceptable. However, if the apical anatomy of the root canal is not conducive to conventional filling then MTA may be the preferred material. MTA is almost certainly the material of choice in the apical area of the invagination as a result of the invariable funnel shape of the opening. Gutta-percha can then be used to backfill the combined lumens and a coronal seal achieved as previously described for type II lesions (Fig. 9).

Once root canal treatment has been concluded, the monitoring of these teeth should follow the same regime as other root canal-treated teeth. The differences that need to be taken into account when assessing healing in comparison with normal teeth is the difference in apical architecture. The apical lesions may be very extensive and of abnormal shape and outline (Figs 8 and 9).

Necrotic pulps in immature teeth

Managing invaginated immature teeth with necrotic pulps is further complicated by the thin root walls and open apices associated with these teeth. Considering the amount of tooth tissue available, it is highly unlikely that the root canal and invagination can or should be kept separate during root canal treatment. However, their combination invariability results in further loss of tooth tissue. As such, the long-term viability of such teeth, even if initial therapy is successful must be considered poor. Treatment planning for these teeth in young patients should be done in conjunction with an orthodontist so that the overall occlusal requirements can be borne in mind. It may be that the objective is to retain the tooth as a 'space maintainer' until the occlusion is fully established.

If an attempt is made to retain the tooth, then a treatment regime as described for type II and III lesions is probably appropriate but with filling achieved using MTA in a similar method as described for noninvaginated teeth (Gaitonde & Bishop 2007).

Conclusion

There is a wide variation in the possible clinical and radiographic presentation of dens invaginatus although there are a number of features that could suggest the presence of an invagination. In addition, there are a number of approaches to the management of this anomaly; however, the overriding objective must be to preserve the health of the pulp if at all possible. This objective can be obtained by achieving early diagnosis and the prophylactic treatment of dens invaginatus regardless of severity. Where disease has developed then a decision has to be made whether to treat the invagination and the pulp separately. Both these alternatives can be achieved using modern endodontic techniques and materials.

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