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REVIEW

Dens invaginatus: aetiology, classification, prevalence, diagnosis, and treatment considerations

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Summary

Dens invaginatus is a malformation of teeth probably resulting from an infolding of the dental papilla during tooth development. Affected teeth show a deep infolding of enamel and dentine starting from the foramen coecum or even the tip of the cusps and which may extend deep into the root. Teeth most affected are maxillary lateral incisors and bilateral occurrence is not uncommon. The malformation shows a broad spectrum of morphologic variations and frequently results in early pulp necrosis. Root canal therapy may present severe problems because of the complex anatomy of the teeth. Aetiology, prevalence, classification, and therapeutic considerations including root canal therapy, apical surgery and prevention of pulpal involvement are reviewed.

Keywords: **dens invaginatus, endodontic treatment.**

Introduction

Dens invaginatus (Fig. 1a–c) is a rare malformation of teeth, showing a broad spectrum of morphological variations. The affected teeth radiographically show an infolding of enamel and dentine which may extend deep into the pulp cavity and into the root and sometimes even reach the root apex (Fig. 2a–c). Tooth crowns as well as roots may exhibit variations in size and form. This kind of tooth malformation was described first by Ploquet in 1794 (Schaefer 1955), who discovered this anomaly in a whale's tooth (Westphal 1965).

Dens invaginatus in a human tooth was first described by a dentist named 'Socrates' in 1856 (Schulze 1970). In 1873 Mühlreiter reported on 'anomalous cavities in human teeth', Baume in 1874 and Busch in 1897 published on this malformation. In 1887 Tomes described the dens invaginatus in his textbook *A System of Dental Surgery*, as follows: 'The enamel investing the crown may be, and often is, perfectly well-developed; but we shall find at some point a slight depression, in the centre of which is a small dark spot. If the tooth be divided through its long axis, we shall find that the dark centre of the depression is in fact the choked-up orifice of a cavity situated within the substance of the tooth, external, however, and perfectly unconnected with the pulp-cavity. 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' (Tomes 1887).

From the 1920s to the 1950s numerous reports on cases of dens invaginatus malformation were published in the dental literature (Miller 1901, Lejeune & Wustrow 1920, De Jonge Cohen 1925, Kronfeld 1934, Rebel & Rohmann 1934, Hammer 1935, Kitchin 1935, Hoepfel 1936, Fischer 1936, Beust & Freericks 1936, Rushton 1937, Euler 1939, Swanson & McCarthy 1947, Zilkens & Schneider-Zilkens 1948, Egli 1949, Gustafson & Sundberg 1950, Bruszt 1950, Munro 1952, Schaefer 1953, Hitchin & McHugh 1954, Logar 1955, Künzel 1956, Petz 1956, Davidoff & Anastassowa 1956, Brabant & Klees 1956). Until 1959 more than 200 papers, mainly case reports, had been published on the dens invaginatus malformation (Grahnen *et al.* 1959). Dens invaginatus malformation again has been a subject of interest in recent years (Wells & Meyer 1993, Piattelli & Trisi 1993, Szajkis & Kaufman 1993, Pecora *et al.* 1993, Altinbulak & Ergül 1993, Skoner & Wallace 1994, Mangani & Ruddle 1994, Benenati 1994, Hülsmann & Radlanski 1994, Hülsmann 1995a,b,

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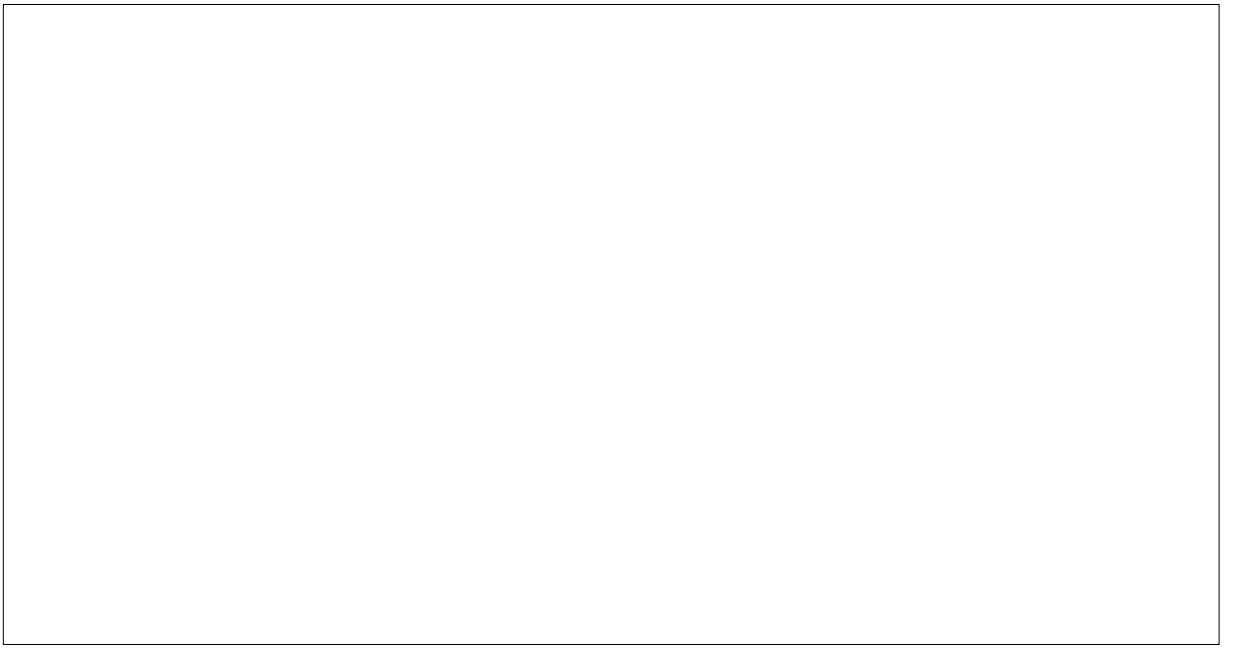

Fig. 1 (a) SEM; (b) microscopic and (c) radiographic appearance of a dental invagination. The invagination is completely filled with debris. At the bottom of the invagination the enamel is missing.

Ikeda *et al.* 1995, Oncag *et al.* 1995, Nagatani *et al.* 1995, Khabbaz *et al.* 1995, Duckmanton 1995, Lindner *et al.* 1995, Bloch-Zupan *et al.* 1995, Olmez *et al.* 1995, Hosey & Bedi 1996).

Synonyms for this malformation are: *Dens in dente*, invaginated odontome, dilated gestant odontome, dilated composite odontome, tooth inclusion, *dentoid in dente*.

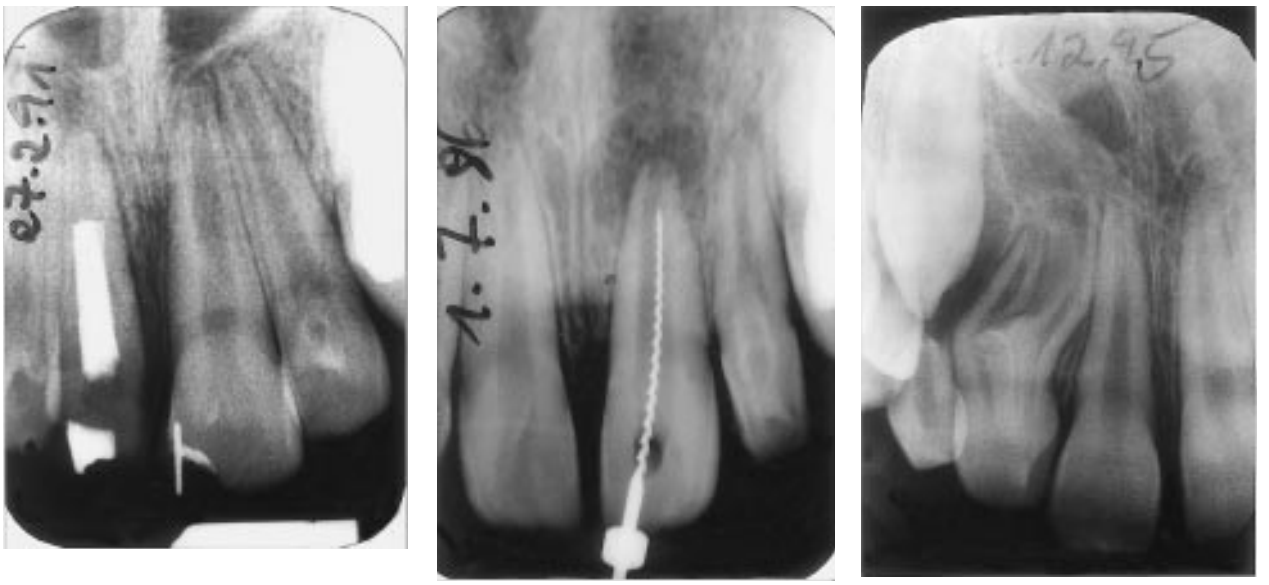

Fig. 2 (a) Invagination in the maxillary left lateral incisor. The invagination is limited to the tooth crown. The malformation was detected by chance. (b) Invagination in the maxillary left lateral incisor. The invagination is extending into the root. At the bottom of the invagination the enamel is missing. The invagination was suspected because of dysmorphic, peg-shaped tooth crown anatomy. (c) Severe case of dens invaginatus with open apex, diverging root and bizarre form of the invagination with a separate apical opening. The malformation was detected because of retarded tooth eruption of tooth 12.

Aetiology of dens invaginatus

The aetiology of dens invaginatus malformation is controversial and remains unclear. Over the last decades several theories have been proposed to explain the aetiology of dental coronal invaginations:

- Growth pressure of the dental arch results in buckling of the enamel organ (Euler 1939, Atkinson 1943).
- Kronfeld (1934) suggested that the invagination results from a focal failure of growth of the internal enamel epithelium while the surrounding normal epithelium continues to proliferate and engulfs the static area.
- Rushton (1937) proposed that the invagination is a result of rapid and aggressive proliferation of a part of the internal enamel epithelium invading the dental papilla. He regarded this a 'benign neoplasma of limited growth'.
- Oehlers (1957a,b) considered that distortion of the enamel organ during tooth development and subsequent protrusion of a part of the enamel organ will lead to the formation of an enamel-lined channel ending at the cingulum or occasionally at the incisal tip. The latter might be associated with irregular crown form.
- The 'twin-theorie' (Bruszt 1950) suggested a fusion of two tooth-germs.
- Infection was considered to be responsible for the malformation by Fischer (1936) and Sprawson (1937).
- Gustafson & Sundberg (1950) discussed trauma as a causative factor, but could not sufficiently explain why just maxillary lateral incisors were affected and not central incisors.

Most authors, meanwhile, consider dens invaginatus as a deep folding of the foramen coecum during tooth development which in some cases even may result in a second apical foramen (Schulze 1970). On the other hand the invagination also may start from the incisal edge of the tooth. Genetic factors cannot be excluded (Grahnen 1962, Casamassimo *et al.* 1978, Ireland *et al.* 1987, Hosey & Bedi 1996).

Classification of dens invaginatus

The first classification of invaginated teeth was published by Hallet (1953). The most commonly used classification proposed by Oehlers (1957a) is shown in Fig. 3. He described the anomaly occurring in three forms:

Type I: an enamel-lined minor form occurring within the confines of the crown not extending beyond the amelocemental junction.

Type II: an enamel-lined form which invades the root but remains confined as a blind sac. It may or may not communicate with the dental pulp.

Type III: a form which penetrates through the root perforating at the apical area showing a 'second foramen' in the apical or in the periodontal area. There is no immediate communication with the pulp. The invagination may be completely lined by enamel, but frequently cementum will be found lining the invagination.

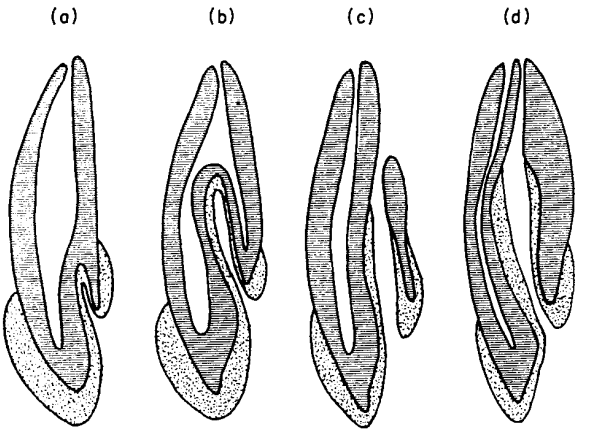

Fig. 3 Classification of invaginated teeth by Oehlers (1957).

Oehlers (1957a,b) also described different crown forms (normal with a deep lingual or palatal pit; conical, barrel-shaped or peg-shaped with an incisal pit) relating to the three groups mentioned above. In addition, Ulmansky & Hermel (1964) and Vincent-Townend (1974) described an 'incipient dens in dente', a deep palatal or lingual pit completely lined by enamel with no communication to the pulp. Oehlers (1958) also presented radicular invaginations.

Schulze & Brand (1972) proposed a more detailed classification (Fig. 4), also including invaginations starting at the incisal edge or the top of the crown and also including dysmorphic root configurations.

Prevalence of dens invaginatus

A summary of the results of investigations on the prevalence of invaginated teeth is presented in Table 1. It is difficult to compare findings because of the differences in study design, sample size and composition, and diagnostic criteria. The teeth most affected are maxillary lateral incisors and bilateral occurrence is not uncommon and occurs in 43% of all cases (Grahnen *et al.* 1959).

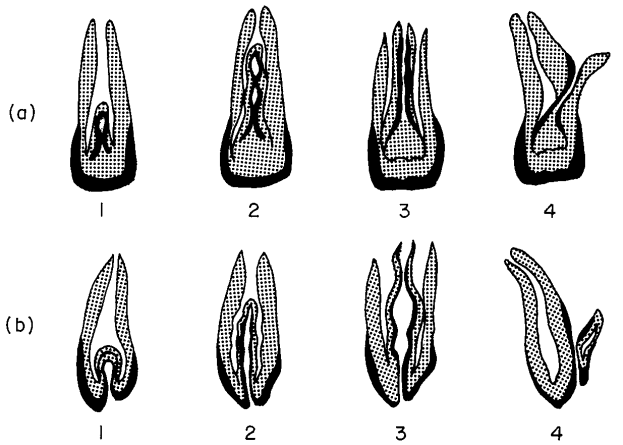

Fig. 4 Classification of dens invaginatus by Schulze & Brand (1972) (from: *Zahnärztliche Welt/Reform* **81**, 569–73, with kind permission).

Swanson & McCarthy (1947) were the first to present bilateral dens invaginatus malformation, Conklin (1968) presented a patient with all maxillary central and lateral incisors affected, and Burton *et al.* (1980) published a case with six teeth involved, the maxillary incisors and also the maxillary canines. Krolls (1969) detected dental invaginations in maxillary central incisors as well as in several maxillary and mandibular bicuspids in one patient. Conklin (1978) found the anomaly in four mandibular incisors in one patient. Double invaginations in one tooth were reported by Rushton (1937), Archer & Silverman (1950), Oehlers (1957a), Grahnen *et al.* (1959), Ulmansky & Hermel (1964), Schulze & Brand (1972), Brill & Phillips (1974), Bhatt & Dholakia (1975), Conklin (1975), Cole *et al.* (1978), Gotoh *et al.* (1979), Mader (1979), Rotstein *et al.* (1987a), and Vairabhaya (1989). Triple invaginations were described by Hitchin & McHugh (1954) and Mader (1977). In rare cases even primary teeth seem to be affected (Rabinowitch 1952).

Cases of dental invaginations in supernumerary teeth have been presented as well as in canines and bicuspids (Archer & Silverman 1950, Schwenzer 1957, Kruse 1962, Klammt 1969, Conklin 1975, Banner 1978,

Table 1 Investigations on the prevalence of dens invaginatus

Author/Country	Year	Sample	Frequency
Mühlreiter (Austria)	1873	500 extracted lateral maxillary incisors (histological investigation)	2.8% of teeth
Atkinson (USA)	1943	500 lateral maxillary incisors	10% of teeth
Boyne (USA)	1952	1000 maxillary incisors	0.3% of teeth
Stephens	1953	150 full-mouth surveys	8%
(unknown)	1953	1000 patients	3.6% (cited by Hovland & Block 1977)
Shafer (USA)	1953	2542 full-mouth surveys	1.3% of patients (cited by Hovland & Block 1977)
Hallet (unknown)	1953	586 full-mouth surveys	6.6% of maxillary lateral incisors 0.5% of maxillary central incisors (cited by Hovland & Block 1977)
Amos (USA)	1955	1000 full mouth surveys 203 full mouth surveys	5.1% of patients 6.9% (students of dentistry)
Grahnen *et al.* (Sweden)	1959	3020 right maxillary incisors	2.7% of patients
Ulmansky & Hermel (Israel)	1964	500 full mouth surveys	2% of patients
Poyton & Morgan (Canada)	1966	5000 full mouth surveys	0.25% of patients (cited by Hovland & Block 1977)
Miyoshi *et al.* (Japan)	1971	extracted maxillary lateral incisors	38.5% of teeth (cited by Gotoh *et al.* 1979)
Fujiki *et al.* (Japan)	1974	2126 lateral maxillary incisors	4.2% of teeth (cited by Gotoh *et al.* 1979)
Thomas (USA)	1974	1886 full mouth surveys	7.74% of patients
Gotoh *et al.* (Japan)	1979	766 lateral maxillary incisors	9.66% of teeth
Ruprecht *et al.* (Saudi Arabia)	1986	1581 full mouth surveys	1.7% of patients
Ruprecht *et al.* (Saudi Arabia)	1987	300 full mouth surveys	10% of patients

Shifman & Tamir 1979, Bottomley & Johnson 1982, Eldeeb 1984, Rotstein *et al.* 1987a, Morfis 1992, Bramante *et al.* 1993, Altinbulak & Ergül 1993, Hülsmann & Radlanski 1994, Tavano *et al.* 1994).

Histological findings

Several reports on microscopic, ultrastructural and microradiographic investigations of teeth with a dens invaginatus malformation show a wide range of findings and thus reproduce the macroscopic variety of this anomaly. The dentine below the invagination may be intact without irregularities (Brabant & Klees 1956, Omnell *et al.* 1960, Piatelli & Trisi 1993) but also may contain strains of vital connective tissue (Omnell *et al.* 1960) or even fine canals with communication to the dental pulp (Kronfeld 1934, Fischer 1936, Hoepfel 1936, Gustafson & Sundberg 1950, Hitchin & McHugh 1954, Oehlers 1957a, Rushton 1958). Some authors reported hypomineralized or irregularly structured dentine (Omnell *et al.* 1960, Vincent-Townend 1974, Beynon 1982). The structure and thickness of the enamel lining the invagination also may vary widely. The enamel was described as irregularly structured by Atkinson (1943), Beynon (1982) and Piatelli & Trisi (1993). Beynon (1982) reported hypomineralized enamel at the base of the invagination whereas Morfis (1992), in a chemical analysis, detected up to eight times more phosphate and calcium compared with the outer enamel, but in his analysis magnesium was missing completely. Bloch-Zupan *et al.* (1995) found differences in structure and compostion between the external and internal enamel. The internal enamel exhibited atypical and more complex rod shapes and its surface presented the typical honeycomb pattern but no perikymata, which, however, were observed on the outer surface of the tooth.

Diagnosis of dens invaginatus

In most cases a dens invaginatus is detected by chance on the radiograph. Clinically, an unusual crown morphology ('dilated', 'peg-shaped', 'barrel-shaped') or a deep foramen coecum may be important hints, but affected teeth also may show no clinical signs of the malformation. As maxillary lateral incisors are the teeth most susceptible to coronal invaginations these teeth should be investigated thoroughly clinically and radiographically, at least in all cases with a deep pit at the foramen coecum. If one tooth is affected in a patient the contralateral tooth should also be investigated. As pulpal involvement of teeth with coronal invaginations may occur a short time after tooth eruption early diagnosis is mandatory to instigate preventive treatment.

Clinical features

The invagination allows entry of irritants into an area which is separated from pulpal tissue by only a thin layer of enamel and dentine and presents a predisposition for the development of dental caries. In some cases the enamel-lining is incomplete (Fig. 1). Channels may also exist between the invagination and the pulp (Kronfeld 1934, Hitchin & McHugh 1954). Therefore, pulp necrosis often occurs rather early, within a few years of eruption, sometimes even before root end closure (Swanson & McCarthy 1947, Ulmansky & Hermel 1964, Stepanik 1968, Ferguson *et al.* 1980, Morfis & Lentzari 1989, Nik-Hussein 1994, Hülsmann & Radlanski 1994) (Fig. 5a, b). Other reported sequelae of undiagnosed and untreated coronal invaginations are abscess formation (Schaefer 1955, Petz 1956, Kendrick 1971, Greenfield & Cambruzzi 1986, Chen *et al.* 1990, Whyman & McFayden 1994), retention of neighbouring teeth (Schaefer 1955, Petz 1956, Conklin 1975, Mader 1977), displacement of teeth (Schaefer 1955, Petz 1956), cysts (Rebel & Rohmann 1934, Schwenzer 1957, Conklin 1978, Klammt 1969, Burzynski 1973, Samimy 1977, Murphy & Doku 1977, Augsburger & Brandebura 1978, Greenfield & Cambruzzi 1986), and internal resorption (Shapiro 1970, Hülsmann & Radlanski 1994) (Fig. 6).

The dental literature on dens invaginatus malformations contains several case reports presenting invaginated teeth coincident with other dental anomalies, malformations and even dental or medical syndromes (Table 2).

Treatment considerations

Preventive and restorative treatment

Teeth with deep palatal or incisal invaginations or foramina coeca should be treated with fissure sealing before carious destruction can occur. A composite restoration and strict periodic review is recommended (Rotstein *et al.* 1987b, Hülsmann & Radlanski 1994). If no entrance to the invagination can be detected and no signs of pathosis are visible clinically and radiographically no treatment is indicated, but strict observation is recommended (Hülsmann 1995b, Duckmanton 1995, Hülsmann 1996).

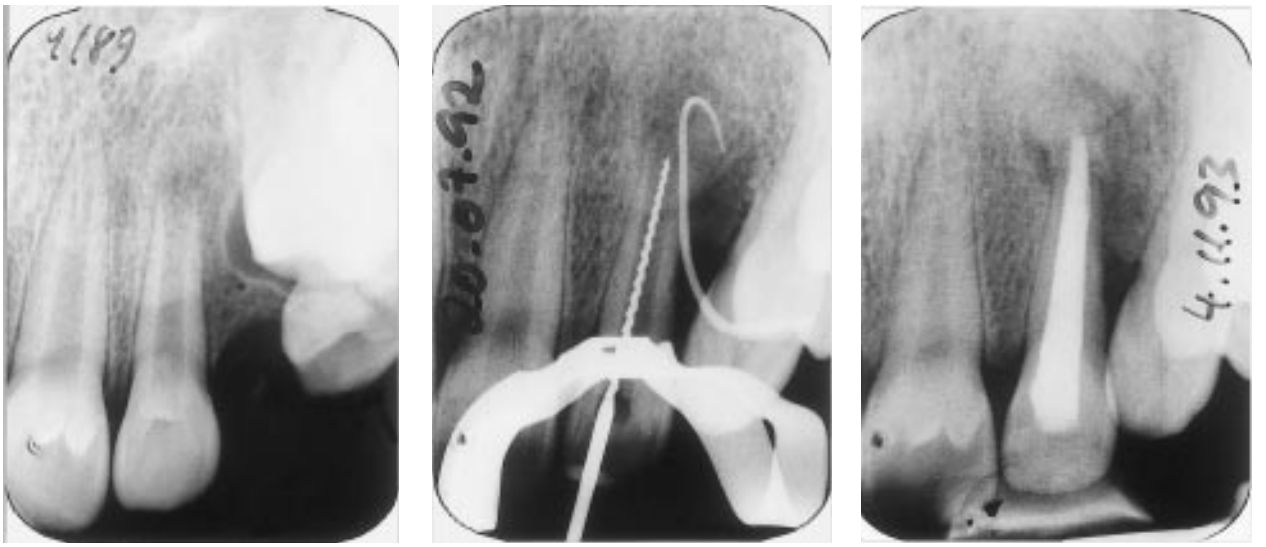

Fig. 5 (a) Small coronal invagination in tooth 22. (b) Three years later arrest of root development and pulp necrosis, with apical periodontitis, and sinus tract have appeared. (c) Fifteen months later: following apexification therapy with calcium hydroxide and obturation of the root canal the periapical status has improved.

Root canal treatment

A review of the literature shows that extraction of teeth with invaginations was the preferred therapy until the 1970s (Hülsmann 1995a). Grossman (1974) and Creaven (1975) were the first to describe root canal treatment of the invagination only (*root invagination treatment*) and Tagger (1977) and Hovland & Block (1977) the first to present cases treated with conventional root canal therapy (Fig. 7a,b). Root canal treatment may present several problems because of the irregular shape of the root canal system(s). If there are no radiographic signs of pulp pathosis and no communication between the invagination and the root canal, root canal treatment or, in minor cases, even a composite or amalgam filling of the invagination will be adequate (DeSmit & Demaut 1982). When the invagination has a separate apical or lateral foramen, root canal treatment of the invagination is indicated (Grossman 1974, Creaven 1975, Bolanos *et al.* 1988, Szajkis & Kaufman 1993, Wells & Meyer 1993, Ikeda *et al.* 1995). In some cases it may be possible to bur through the invagination to get access to the apical foramen. When these minor forms of invaginations are eliminated root canal therapy in most cases will not present further problems. In certain cases the invagination has to be treated as a separate root canal (Cole *et al.* 1978, Zillich *et al.* 1983, Eldeeb 1984, Greenfield & Cambruzzi 1986, Mangani & Ruddle 1994, Khabbaz *et al.* 1995).

When pulp necrosis occurs before root-end closure, apexification procedures with calcium hydroxide may be necessary (Ferguson *et al.* 1980, Morfis & Lentzari 1989, Vairabhaya 1989, Hülsmann & Radlanski 1994, Nagatani *et al.* 1995) (Fig. 5a–c).

Table 2 Dental anomalies described in association with dens invaginatus

Microdontia	Casamassimo *et al.* 1978
Macrodontia	Ekman-Westberg & Julin 1974
Hypodontia	Hülsmann 1995c
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
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 1992
Amelogenesis imperfecta	Kerebel *et al.* 1983
Invagination in an odontome	Hitchin & McHugh 1954
Multiple odontomes	Robbins & Keene 1964
Coronal agenesis	Hicks & Flaitz 1985
Williams syndrome	Oncag *et al.* 1995

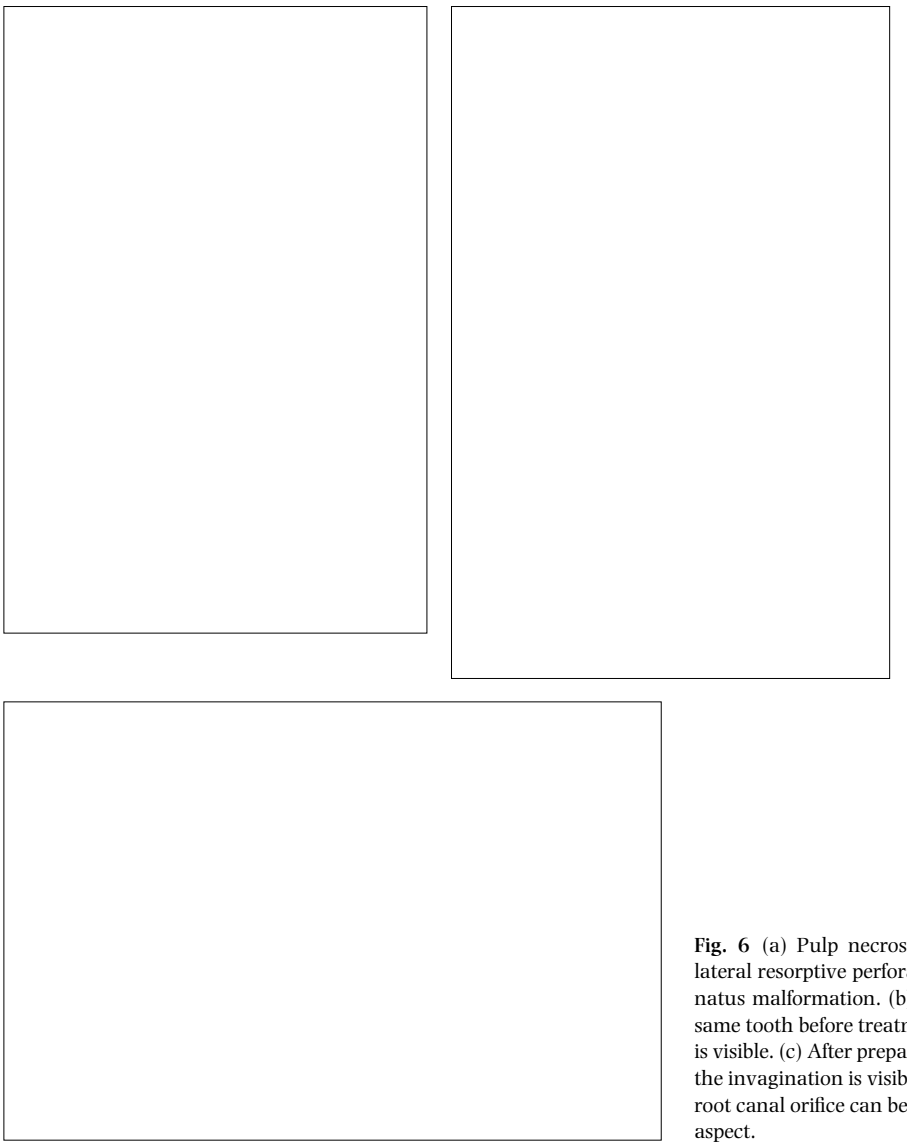

Fig. 6 (a) Pulp necrosis, apical periodontitis, sinus tract, and lateral resorptive perforation in tooth 12 showing a dens invaginatus malformation. (b) Clinical view of the tooth crown of the same tooth before treatment. A deep foramen coecum with caries is visible. (c) After preparation of the access cavity the entrance to the invagination is visible at the palatal aspect (arrow). The main root canal orifice can be seen at the top of the cavity at the buccal aspect.

The large and irregular volume of the root canal system makes proper shaping and cleaning difficult. Irrigation, supported by ultrasonic cleaning of the root canal system has been described as an efficient means of disinfection (Cunningham *et al.* 1982) and has therefore been recommended for cleaning of the complex morphology of the root canal system in teeth with dens invaginatus (Skoner & Wallace 1994). For obturation of such teeth warm gutta-percha techniques including vertical condensation or thermoplastic filling techniques have been recommended (Rotstein *et al.* 1987b, Hülsmann & Radlanski 1994, Mangani & Ruddle 1994).

Surgical treatment

Surgical treatment should be considered in cases of endodontic failure and in teeth which cannot be treated non-surgically because of anatomical problems or failure to gain access to all parts of the root canal system (Harnisch 1970, Hata & Toda 1987, Teplitsky & Singer 1987, Rotstein *et al.* 1987b, Kulild & Weller 1989, Suchina *et al.* 1989, Hülsmann & Radlanski 1994, Benenati 1994, Olmez *et al.* 1995) (Fig. 8a,b). Cole *et al.* (1978) and Lindner *et al.* (1995) even proposed intentional replantation with retrograde surgery in otherwise hopeless cases.

Fig. 7 (a) Right maxillary lateral incisor in the same patient as in Fig. 5. The invagination was detected by preventive radiographic examination, clinically no invagination nor carious lesion were detected. The invagination has resulted in an internal resorption with perforation. (b) Obturation with injectable gutta-percha, resulting in a slight lateral overfill.

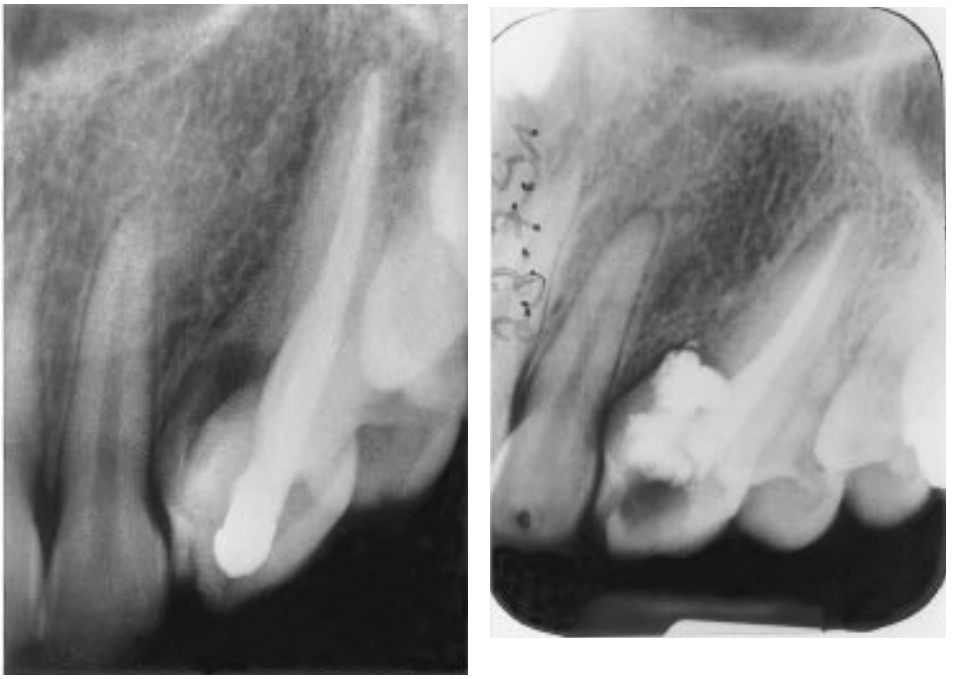

Fig. 8 (a) Radiograph of tooth 23 showing a bizarre lateral coronal invagination which seems to be open to the lateral periodontium. The main root canal was root canal treated, but no communication to the invagination could be detected. (b) As no access to the invagination was found coronally the invagination was treated surgically. Probably root canal treatment of the main root canal would not have been necessary.

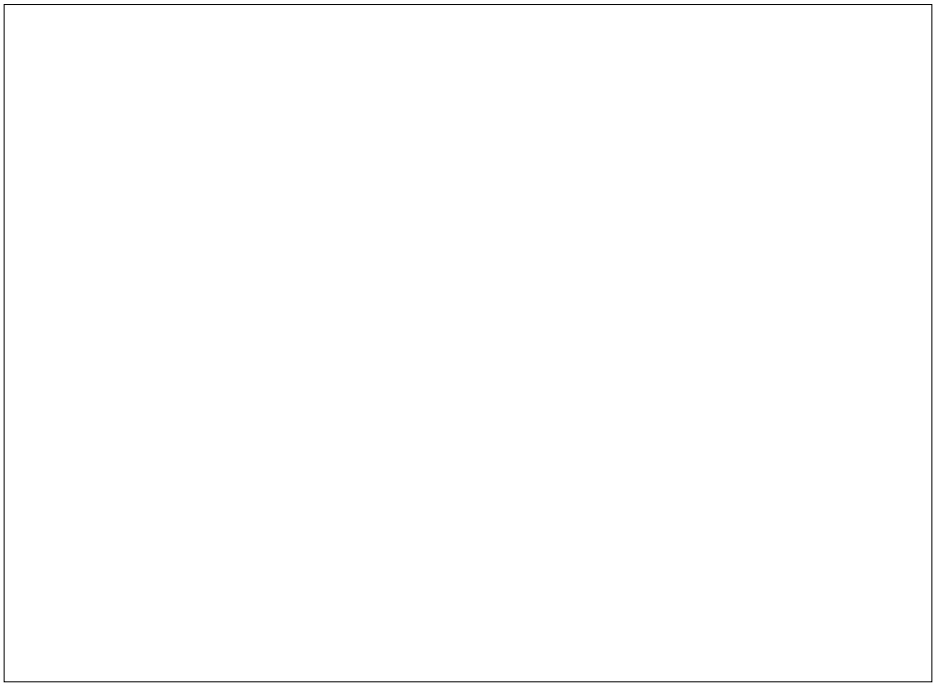

Fig. 9 (a) Severe dens invaginatus malformation with acute apical abscess formation. The tooth was judged inoperable and extracted by a general dental practitioner. (b) The photograph of the extracted tooth shows the invagination extending beyond the apex.

Fig. 10 Severe invagination malformation of tooth 22 resulting in acute apical abscess formation. The tooth was judged inoperable and extracted.

Extraction

Extraction is indicated only in teeth with severe anatomical irregularities that cannot be treated non-surgically or by apical surgery, and in supernumerary teeth (Figs 9a,b and 10). Additionally Rotstein *et al.* (1987b) advocated extraction when abnormal crown morphology presents aesthetic or functional problems.

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