20 Variations in the Anatomy of the Teeth

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20.1 Introduction

For the success of dental therapy, knowledge of tooth anatomy cannot be ignored. It is essential to know the normal configurations of the teeth and their variations. There are numerous variations in the internal anatomy of teeth due to developmental anomalies, hereditary factors, trauma, etc.

20.1.1 Variations in Development

1. Amelogenesis Imperfecta

   Amelogenesis imperfecta (AI) comprises a group of hereditary disorders of dental enamel. The reported incidences range between 43:10,000 in Turkey (Altug-Atac and Erdem 2007), 14:10,000 in Sweden (Bäckman and Holm 1986), 10:10,000 in Argentina (Sedano 1975), and 1.25:10,000 in Israel (Chosack et al. 1979). The structure and clinical appearance of the enamel are affected in both primary and permanent dentition, and there is hypomineralization and/or hypoplasia with discoloration, sensitivity, and fragility. The main aim of treatment should be early diagnosis, pain management, prevention, stabilization, restoration of defects, and regular maintenance (Fig. 20.1).
2. Enamel Pearl

   Ectopic globules of enamel, or so-called enamel (enamelous) pearls, droplets, globules, nodules, knots, or exostoses, are a developmental anomaly of teeth (Moskow and Canut 1990). They can be either internal or external, the former being more common on the root surface. Internal ectopic globules are

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referred to as intradental, interdental, or intradentinal enamel pearls. The mean overall prevalence of enamel pearls is 2.69%, but the prevalence for molars is 2.28% (Moskow and Canut 1990). Clinically, enamel pearl is a risk for localized deep periodontal pockets since it compromises the attachment of the periodontal ligament.

3. Enamel Projection

   Cervical enamel projection is a developmental abnormality causing focal triangular extension of the enamel beyond the normal CEJ to the furcation area. Cervical enamel projection can be considered a secondary etiological factor for periodontal breakdown and attachment loss due to the lack of connective tissue attachment (Swan and Hurt 1976). Clinically, removal of ectopic enamel by periodontal surgeries is generally recommended to allow the connective tissue attachment to form (Fig. 20.2).

4. Gemination

   Gemination occurs when a single tooth bud divides into two separate entities. This results in a structure with two completely or incompletely separated crowns with a single root and root canal. Consequently, the patient has a bigger

Fig. 20.1 Amelogenesis imperfecta (Courtesy of Dr. Teppei Tsukiyama)

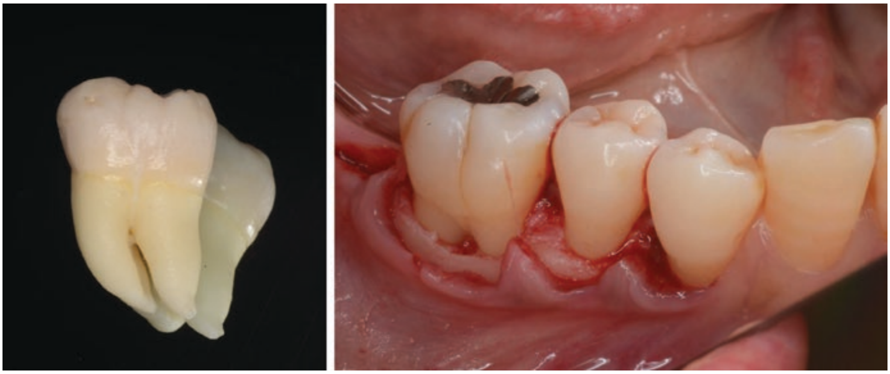

Fig. 20.2 Enamel projection (Courtesy of Dr. Teppei Tsukiyama)

tooth, but the number of teeth in the affected arch is normal when the geminated tooth is counted as one. This condition can also cause impaction because the crown of the geminated tooth is bigger than normal. Gemination in the anterior maxillary region is commonly documented in the literature (Dexton et al. 2011). The etiology is unknown, but trauma and familial tendency have been proposed (Järvinen et al. 1980). Gemination is observed in both deciduous and permanent dentitions (O Carroll 1990). Clinically, fissures or grooves in the union between the teeth are a risk for caries and periodontal disease. Also, owing to the abnormal morphology of the crown and the complexity of the root canal system in geminated teeth, root canal treatment protocols require special attention. CBCT is advocated to help the clinician understand the anatomy (Matherne et al. 2008) (Fig. 20.3).

5. Fusion

Fusion of teeth is a developmental anomaly that results in the union of two normally separated tooth germs. Fused teeth can have separate or fused pulp spaces (Neville et al. 1993). The incidence ranges between 0.3% and 3.8% in the general population (Yusof 1990). The most important factor distinguishing this condition from germination is that fusion usually leads to a reduced number of teeth in the dentition. As with germination, the anomaly entails a high risk for dental caries, periodontal disease, and spacing between teeth (Fig. 20.3).

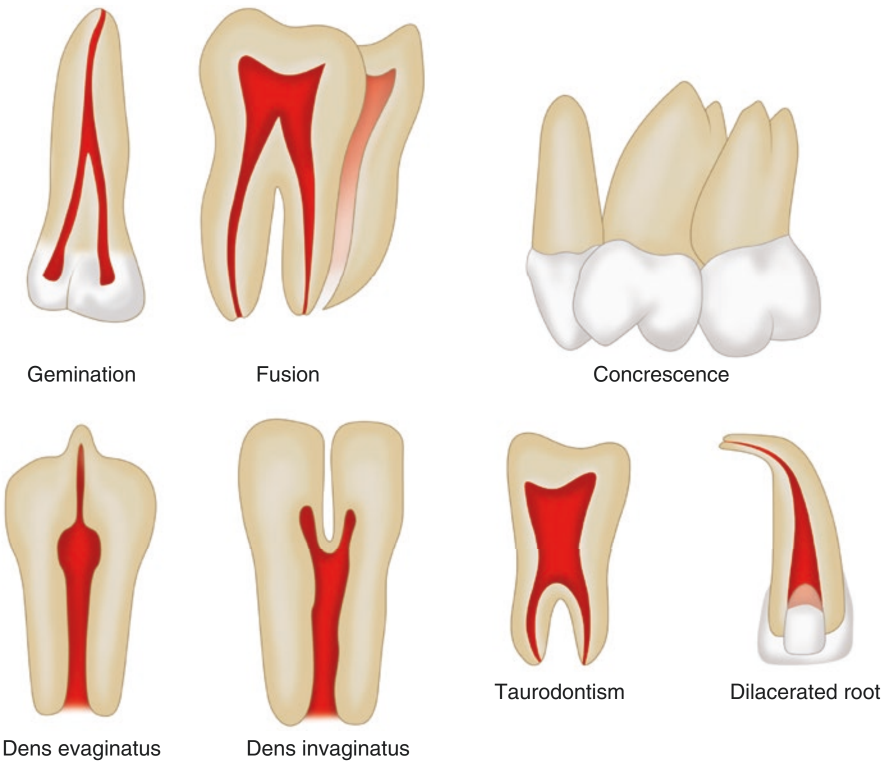

Fig. 20.3 Schematic representation of tooth anomalies

6. Concrescence

   Concrescence is an uncommon developmental anomaly that occurs after root formation is complete: there is a confluence of the cementum of two teeth at the root level but not the dentine. The reported frequency of concrescence is 0.8% in adult teeth and 0.2–3.7% in deciduous teeth, and the incidence is highest in the posterior maxilla (Law et al. 1994). Some reported complications of concrescence include periodontal problems (Mohan 2014). Owing to their large mesiodistal dimensions, extractions of concrescent teeth can be difficult and can result in alveolar bone fracture and tooth fracture, or in sinus opening (Fig. 20.3).

7. Taurodontism

   Taurodontism is a morpho-anatomical change in tooth shape in which the body of the tooth is enlarged and the roots are small. The pulp chamber of this tooth is extremely large with a greater apico-occlusal height than normal. From a periodontal standpoint, taurodont teeth can offer a favorable prognosis in specific cases since there can be furcations only few millimeters above the root apex. From an endodontist's view, taurodontism presents a challenge during negotiation, instrumentation, and obturation in root canal therapy as the pulp lacks the normal constriction at the cervical level of the tooth. Taurodontism is often associated with syndromes such as Klinefelter and Down syndromes. Its etiology is commonly attributed to the failure of invagination of the epithelial root sheath sufficiently early to form the cynodont (Witkop 1971) (Figs. 20.3 and 20.4).

8. Talon Cusp

   Talon cusp is a developmental anomaly in which an accessory cusp-like or tooth-like structure forms from the cingulum area or cementoenamel junction to the incisal edge of the maxillary or mandibular anterior teeth. The reported prevalence is between 0.06% and 7.7% (Lee et al. 2006). The etiology is not completely understood. Clinically, we have to be very careful in treating talon cusps since the condition can cause esthetic, caries, and periodontal problems.

Fig. 20.4 Taurodont tooth #18 (arrow) (Courtesy of Dr. Atsushi Fujimura)

9. Dilaceration

   Dilaceration is the result of a developmental anomaly leading to an extraordinarily sharp bend in the roots of the teeth. Two possible etiologies of dilaceration are related to trauma and to disturbances during root development. Dilaceration can be seen in both the permanent and deciduous dentitions, and it is more commonly found in the posterior teeth and in the maxilla. Radiographic information from periapical radiographs or CBCT facilitates the correct diagnosis of root dilacerations. The excessive root curvature obviously complicates dental treatment especially endodontic procedures (Fig. 20.3).

10. Dentinogenesis Imperfecta

    Dentinogenesis imperfecta is the most common type of developmental anomaly of dentine. Dentitions are affected by an opalescent brown discoloration, and because of the reduced support of the dentine, the overlying enamel fractures readily. There is also rapid wear and attrition of the teeth. There are various degrees of partial or total precocious pulp obliteration. As dentinogenesis imperfecta is associated with rapid wear, attrition of the teeth, and crown fractures, protection from tooth wear soon after eruption is strongly recommended (Seow and Taji 2011) (Fig. 20.5).

11. Dentine Dysplasia

    Clinically, the crowns of the affected teeth are usually normal in shape and color but sometimes slightly opalescent. Radiographically, the pulp chambers are largely or completely obliterated and the roots are short, often pointed with apical radiolucencies in the absence of caries.

12. Palatogingival groove

    Palatogingival groove (PGG) is an anomaly in the maxillary anterior teeth, often with a deep narrow periodontal pocket that communicates with the pulp causing endodontic-periodontal lesions. PGG can be classified by its location, extent, complexity, etc. The groove acts as a trap that can harbor plaque and bacteria. Three strategies are advocated for treating teeth with PGG: (1) microorganism elimination, (2) permanent sealing of the root groove that communicates between the root canal system and the periodontium, and (3)

Fig. 20.5 Dentinogenesis imperfecta (Courtesy of Dr. Teppei Tsukiyama)

periodontal regeneration and complete healing of the periodontium. If the dental pulp is involved, endodontic treatment is recommended before the periodontal approach (Fig. 20.6).

13. Dens in Dente or Dens Invaginatus

Dens invaginatus is a developmental anomaly involving invagination of the enamel organ into the dental papilla during morphodifferentiation, which results in a small tooth within the pulp chamber. Types of dens invaginatus can be classified as follows, according to Oehler (1957) (Fig. 20.7):

- Type I: The invagination is minor and enamel-lined; it is confined within the crown of the tooth and does not extend beyond the level of the external enamel-cement junction.
- Type II: The invagination is enamel-lined and extends into the pulp chamber but remains within the root canal with no communication with the periodontal ligament.
- Type III A: The invagination extends through the root and communicates laterally with the periodontal ligament space through a pseudo-foramen.

Fig. 20.6 Palatogingival groove (Courtesy of Dr. Teppei Tsukiyama)

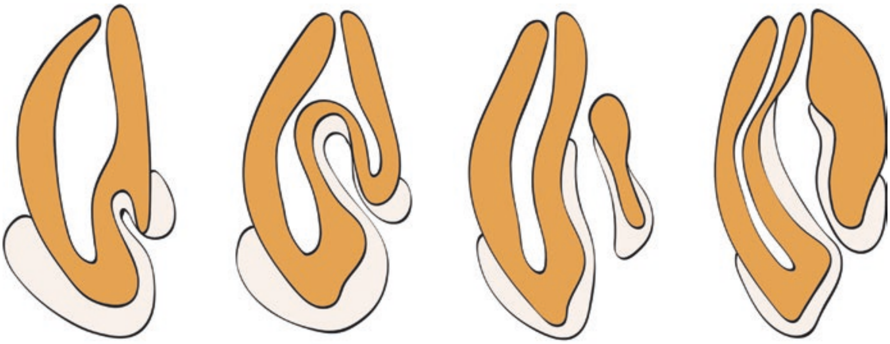

Fig. 20.7 Oehler's classification of dens invaginatus (coronal types) cited from Oehlers (1957)

There is usually no communication with the pulp, which lies compressed within the root.

- Type III B: The invagination extends through the root and communicates with the periodontal ligament at the apical foramen. There is usually no communication with the pulp.

The condition is most commonly found in the maxillary lateral incisors. It predisposes the tooth to early decay and therefore pulpitis. Conventional radiography in the classification and management of dens invaginatus is being superseded by the increasing availability of CBCT imaging (Ball et al. 2013). In Type III lesions, any infection within the invagination can lead to inflammation within the periodontal tissues giving rise to a "peri-invagination periodontitis." The treatment options are prophylactic or preventive sealing of the invagination, root canal treatment, endodontic apical surgery, intentional replantation, and extraction. The prognosis following any treatment is often dubious (Figs. 20.3 and 20.8).

14. Dens Evaginatus

Dens evaginatus is most common in the mandibular premolars and in individuals of Asian ancestry. Clinically, it appears as an anomalous small tubercle

Fig. 20.8 Dens invaginatus type II tooth #10 (Courtesy of Dr. Atsushi Fujimura)

or bulge on the occlusal surface. Occlusal abrasion or tubercle fracture causes early exposure of the pulp horn that extends into the tubercle. This can further result in periapical pathology. To prevent tubercle fractures, the tubercle is removed with a burr and the tooth is capped, followed by a good sealing restoration with composite (Fig. 20.9).

20.2 Variations in Pulp Cavity Due to Pathology

20.2.1 Pulp Stones and Calcifications

Pulp stones are usually found in the coronal pulp in the form of discrete, concentric calcifications, whereas in the radicular pulp, the calcification is more likely to be

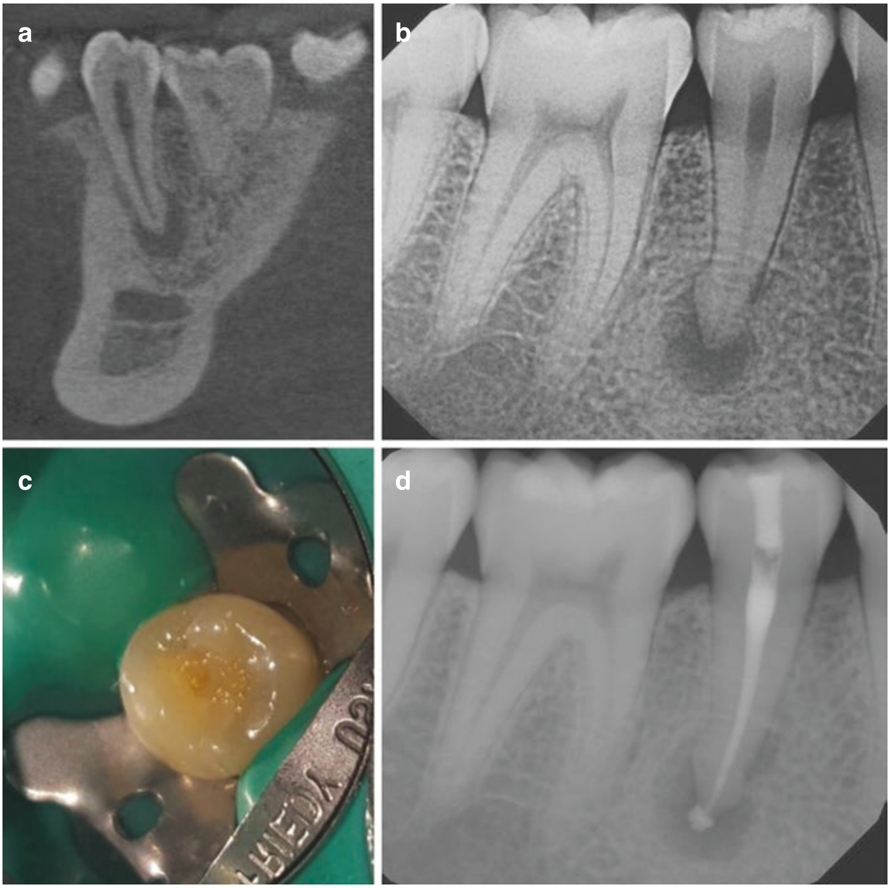

Fig. 20.9 Dens evaginatus (Courtesy of Dr. Jae Ha Jung). (**a**) Preoperative CBCT. (**b**) Preoperative radiograph. (**c**) Fractured tubercle. (**d**) Postoperative radiograph

diffuse (Sundqvist and Lerner 1996). Typically, calcification of root canals begins at the coronal aspect and extends to the apical canal. The clinical significance of pulp stones and calcifications is the obstruction of endodontic treatment. Magnification and illumination are essential for identifying and treating calcified canals. CBCT can also assist the clinician by locating the pulp stones and identifying the severity of the calcification during perioperative assessment (Kuyk and Walton 1990).

Pulp stones or denticles were once classified as true or false, depending on the presence of a tubular structure. This classification has been challenged, and a new nomenclature based on the genesis of the calcification has been suggested. Three types of pulp stones have been also classified according to location as follows: free stones, attached stones, and embedded stones.

Extensive calcification, also known as calcific metamorphosis, occurs due to trauma, caries, periodontal disease, or irritants. Palpation and percussion are usually within normal limits. This condition is not pathological and does not require treatment (Figs. 20.10 and 20.11).

20.2.2 Resorption

Resorption can be classified as internal or external. Pulp-periodontal communications due to resorptions are often complex.

Limited internal resorption can be managed without great difficulty, but external apical resorption can drastically alter the anatomy of the apex or the root surface.

1. Internal Resorption

   Internal resorption is an intracanal resorption commonly seen in the central maxillary incisors, though any tooth can be affected. It is characterized by oval enlargement of the root canal space. A possible etiology is inflammation in the pulp. The pulp is transformed into vascularized inflammatory tissue with dentinoclastic activity; this leads to the resorption of the dentinal walls (Walton and Leonard 1986). Teeth with intracanal resorptive lesions usually respond

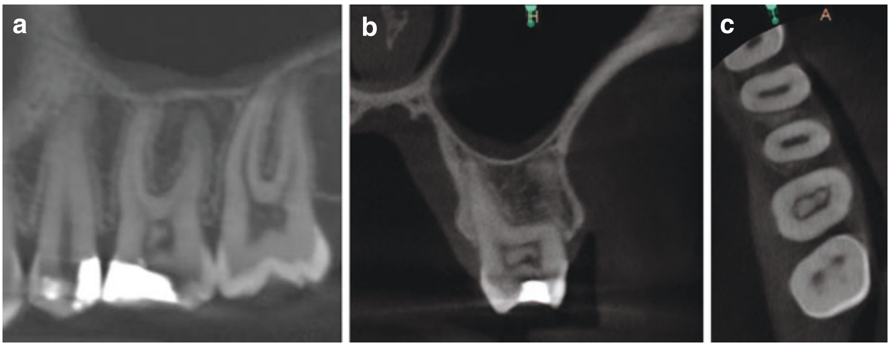

Fig. 20.10 Pulp stone. (**a**) Sagittal plane. (**b**) Frontal plane. (**c**) Axial plane

Fig. 20.11 Calcific metamorphosis

within normal limits to pulpal and periapical tests and are asymptomatic clinically. As long as there is no communication to the periodontium, the prognosis is favorable. Pink spots in the crown are often observed with advanced internal resorption involving the pulp chamber.

Radiographs especially CBCT can reveal radiolucency with irregular enlargement of the root canal anatomy. Removal of the inflamed tissue and completion of root canal treatment will arrest the resorption. If the root canal procedure is not done immediately, these lesions tend to be progressive and eventually perforate to the periodontium. Perforating internal resorptions often create operative difficulties and a guarded prognosis. With internal resorption, it is difficult to negotiate the canal from the coronal portion to the apex. Also, it is difficult to remove tissues and bacteria from the resorptive defect (Fig. 20.12).

2. External Resorption

External root resorption is initiated in the periodontium and affects the external or lateral surface of the root. It is often observed in trauma cases, especially

Fig. 20.12 Internal resorption (Courtesy of Dr. Jae Ha Jung)

affecting replanted avulsed teeth. Three types have been identified: surface, inflammatory, and replacement (Trope et al. 1992; Andreasen and Andreasen 1992).

(a) Surface Resorption

This type, also known as "repair-related resorption," is transient and shows as lacunae of resorption in the cementum. It is not usually visible on radiographs. Once the resorption is arrested, the lacunae are repaired by the deposition of new cementum. No treatment is usually indicated.

(b) Inflammatory (Infection-Related) Resorption

This type of resorption is a response to an infected root canal system in conjunction with injury to the periodontal ligament. It often occurs when the teeth are traumatized with the need for replantation, in addition to other types of luxation injuries. It is characterized by loss of tooth structure and adjacent alveolar bone. Inflammatory resorption is usually arrested after removal of the necrotic, infected pulp (Fig. 20.13).

(c) External Replacement (PDL-Related) Resorption

In this type of resorption, also known as ankylosis, the tooth structure is resorbed and replaced by bone. The common etiology is contusion of the PDL during intrusion, lateral luxation, or avulsion with subsequent replantation. When large areas of the PDL are traumatized, competitive wound healing processes begin, eventually resulting in replacement resorption. The

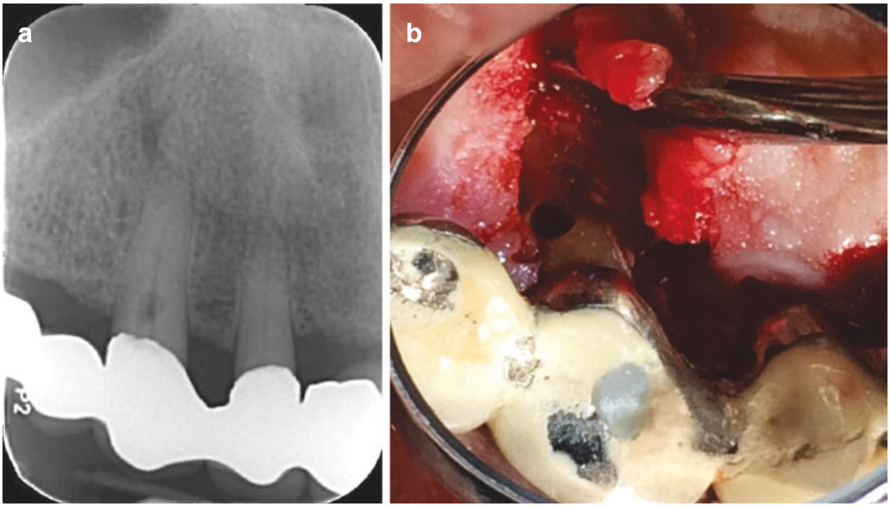

Fig. 20.13 External resorption. (**a**) Preoperative radiograph. (**b**) Surgical repair

characteristics of ankylosis are failure of the tooth to erupt along with adjacent teeth, lack of physiological mobility, and a “solid” metallic sound on percussion. Currently, no treatment to arrest replacement resorption has proved effective. It tends to continue until the root is replaced by bone.

20.3 Root Canal Anatomy

The root canal is the portion of the pulp cavity that extends from the canal orifice to the apical foramen. Its shape varies with the size, shape, and number of roots in different teeth. Root canals are commonly curved along their length and gradually sharpen. The root canal system is complex; canals can branch, divide, and rejoin. The number of root canals does not always correspond to the number of roots; roots that are elliptical or have a concave surface frequently have more than one canal. According to Orban (1957), the shape of the canal is largely determined by the shape of the root. Root canals can be round, tapering elliptical, broad, thin, etc., but it is important to know that a canal is seldom round at any level. This makes it hard clinically to clean and shape the root canal system with round-shaped instrument.

For good clinical practice and successful endodontic procedures, we need to know the normal root canal morphology and its frequent variations. Several studies have demonstrated these aspects of the root canal system. This knowledge helps clinicians during actual root canal procedures.

Weine (1996) categorized the canal systems in any root into four basic types. Using precise techniques, Vertucci (1984) established eight different pulp space configurations rather than four, which can be described briefly as follows:

- Type I: A single canal extends from the pulp chamber to the apex (one canal).
- Type II: Two separate canals leave the pulp chamber and join short of the apex to form one canal (coronal-apical, 2-1).
- Type III: One canal leaves the pulp chamber and divides into two in the root; the two then merge to exit as one canal (coronal-middle-apical, 1-2-1).
- Type IV: Two separate, distinct canals extend from the pulp chamber to the apex (two canals).
- Type V: One canal leaves the pulp chamber and divides short of the apex into two separate, distinct canals with separate apical foramina (coronal-apical, 1-2).
- Type VI: Two separate canals leave the pulp chamber, merge in the body of the root, and separate short of the apex to exit as two distinct canals (coronal-middle-apical, 2-1-2).
- Type VII: One canal leaves the pulp chamber, divides and then rejoins in the body of the root, and finally separates into two distinct canals short of the apex (pulp chamber-coronal-middle-apical, 1-2-1-2).
- Type VIII: Three separate, distinct canals extend from the pulp chamber to the apex (three canals) (Fig. 20.14).

Gender, racial, and ethnic data should be considered during preoperative evaluation, especially for a root canal procedure. Specific types of canal morphology occur in different racial groups.

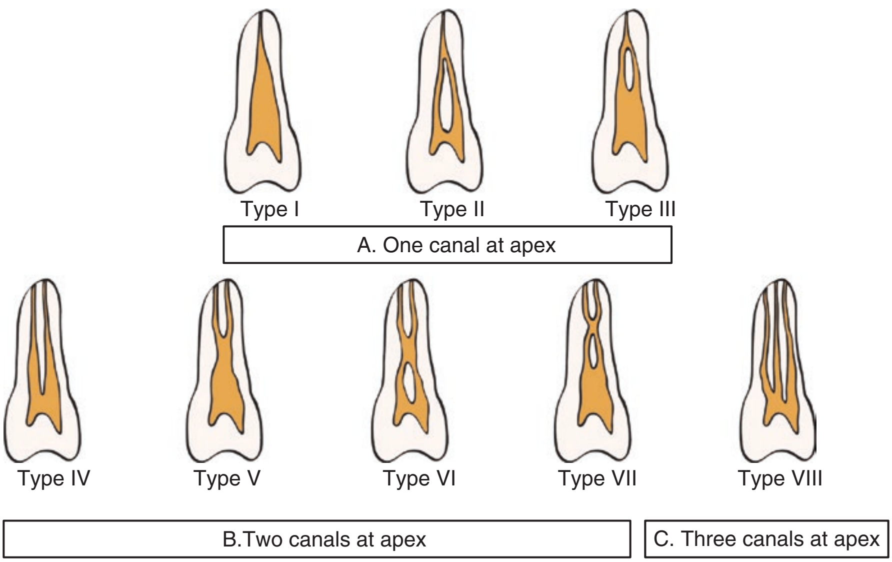

Fig. 20.14 Diagrammatic representation of canal configurations based on the work of Vertucci (1984). (**a**) One canal at apex. (**b**) Two canals at apex. (**c**) Three canals at apex

20.3.1 Other Variations

20.3.1.1 C-Shaped

A C-shaped canal is very common on the mandibular molars especially among Asians and those of Asian descent (Zheng et al. 2011). The main etiology of this anomaly is the failure of Hertwig's epithelial root sheath to fuse on either the buccal or lingual root surface. A C-shaped canal system can be observed in many variations in root and canal morphology. It can vary along the root depth so the appearances of the orifices are not necessarily good predictors of the actual canal anatomy. Fan et al. (2004) classified C-shaped canal configurations into five different types (Fig. 20.15):

- Category I (C1): The shape is an uninterrupted "C" with no separation or division.
- Category II (C2): The canal shape resembles a semicolon resulting from a discontinuity in the "C" outline, but either angle α or β should be no less than 60°.
- Category III (C3): Two or three separate canals and both angles, α and β, are less than 60°.
- Category IV (C4): Only one canal, which is round or oval in cross section.
- Category V (C5): No canal lumen can be observed (usually seen near the apex only).

The access cavity for teeth with a C-shaped root canal system varies considerably and depends on the pulp morphology of the specific tooth. Owing to the complex anatomy, teeth with C-shaped anatomy pose considerable technical difficulties. Patients with such teeth should be considered for referral to endodontists (Fig. 20.16).

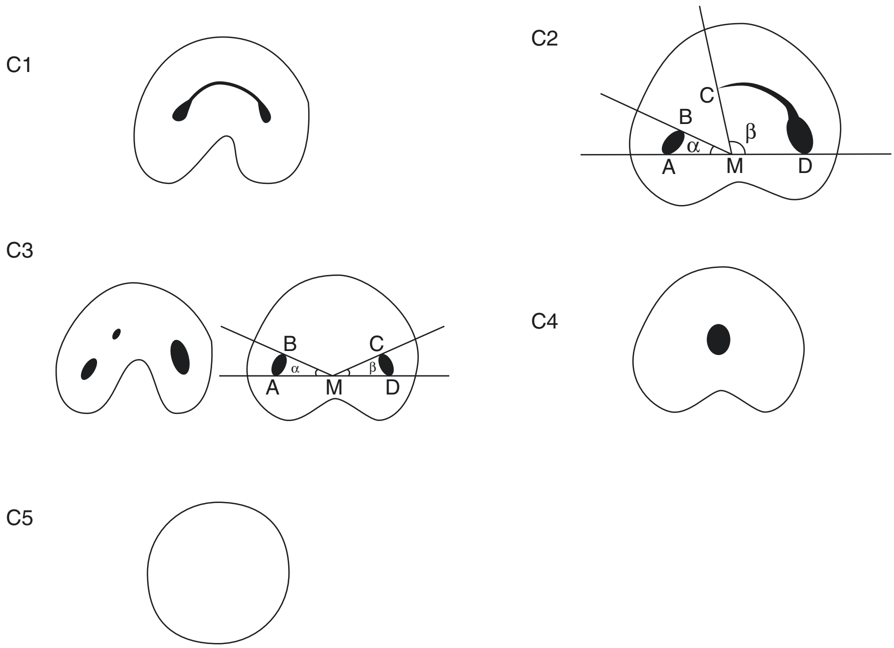

Fig. 20.15 Classification of C-shaped canal configuration (Fan et al. 2004)

20.3.1.2 Isthmus

Isthmus is defined as narrow, ribbon-shaped passage or anatomical communication between two root canals that contain pulp or pulpally derived tissue. It is commonly found in teeth with multiple roots. These structures can store various amounts of tissue, and the tissues often contain bacteria and their byproducts if the pulp is infected. Isthmus can be complete or incomplete. However, the isthmus should ideally be cleaned, shaped, and obturated.

Kim and colleagues offered a classification of isthmus (Kim et al. 2001). Type I is an incomplete isthmus; it is a faint communication between two canals. Type II is characterized by two canals with a definite connection between them (complete isthmus). Type III is a short, complete isthmus between two canals. Type IV is a complete or incomplete isthmus among three or more canals. Type V is marked by two or three canal openings without visible connections (Fig. 20.17).

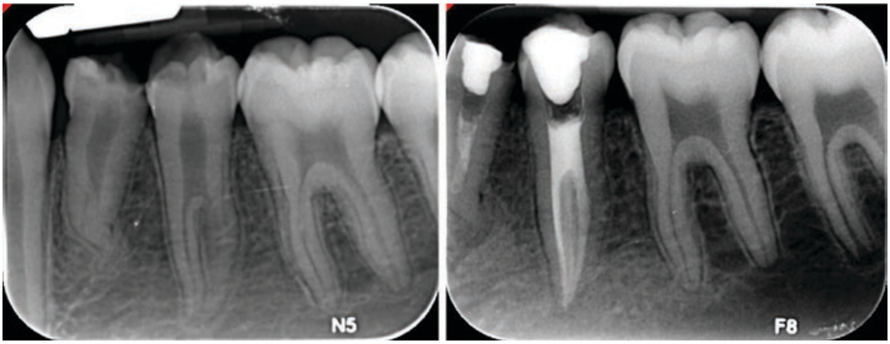

Fig. 20.16 C-shaped root canal #20

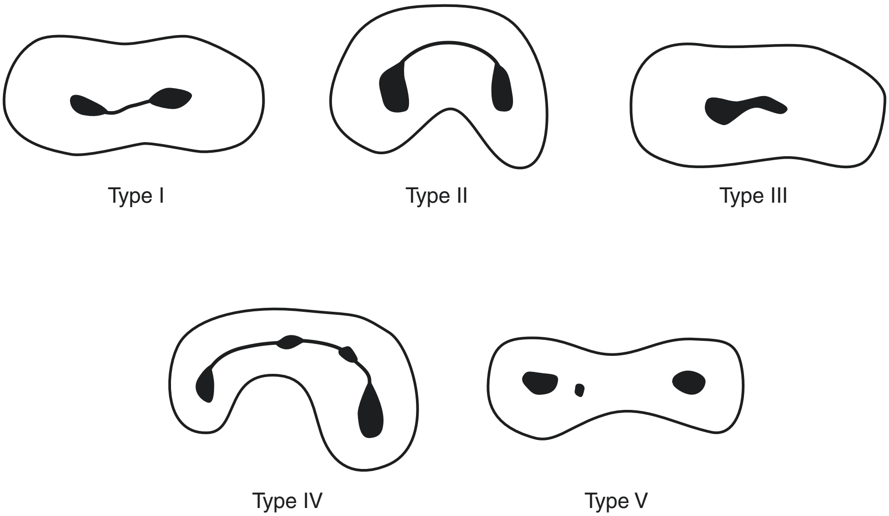

Fig. 20.17 Schematic representation of isthmus classifications (Kim et al. 2001)

New technologies such as CBCT can provide three-dimensional morphology information concerning many more irregular and challenging root canal anatomies (Peters et al. 2000).

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