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Tooth Development

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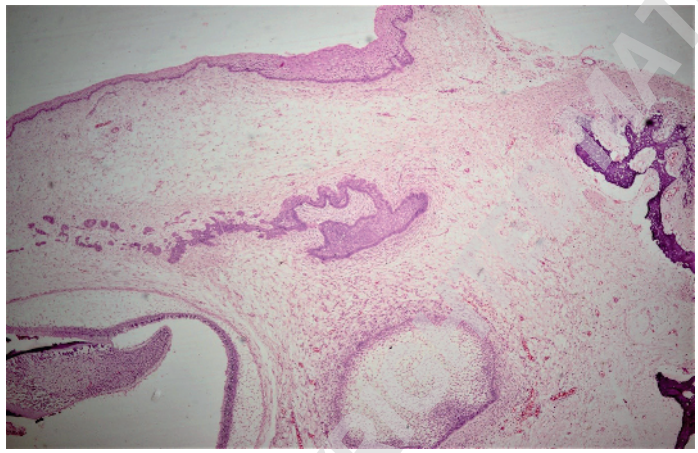

Figure 1.1 H and E stained section showing tooth development.

Tooth development starts on the 37th day of gestation with the formation of primary epithelial bands in the place of future upper and lower jaws. These horse-shoe-shaped bands correspond to the future dental arches. These epithelial bands then form two ingrowths called dental lamina (lingually positioned) and vestibular lamina (buccally positioned). These ingrowths extend into the mesenchyme which is surrounded by the neural crest cells. The vestibular lamina proliferates within the mesenchyme and leads to the formation of the vestibule (between the cheek and tooth-bearing portion of the jaw). The dental lamina gives rise to epithelial outgrowths toward the mesenchyme due to continuous proliferative activity which correspond to the location of forthcoming deciduous teeth. The tooth development is divided into the following stages: bud, cap, and bell (early and late). These stages along with the changes happening in the tooth germ are discussed in detail in the following sections.

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Companion website: www.wiley.com/go/farooq/oral_histology

1.1 Bud Stage

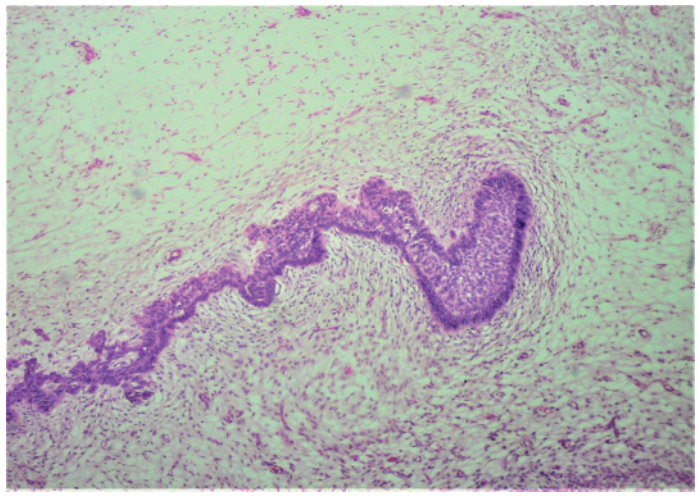

Figure 1.2 H and E stained section showing the bud stage of tooth development.

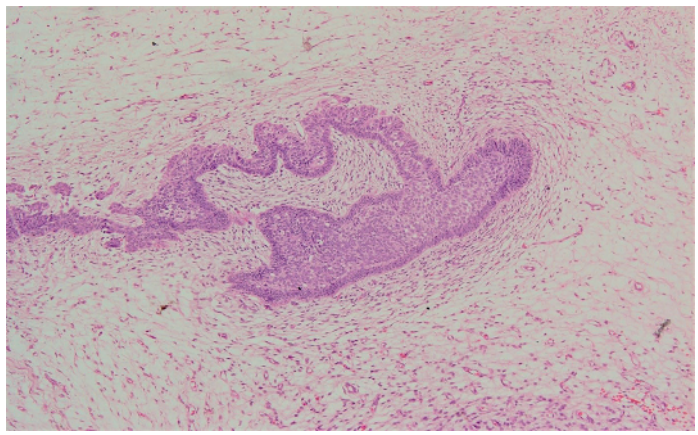

Figure 1.3 H and E stained section showing the bud stage of tooth development.

1.1.1 Description

The bud stage is the first stage of tooth development. It represents the first epithelial intrusion into the ectomesenchyme. The cells of the epithelium show minimal changes and the ectomesenchymal cells surround the epithelial bud. Due to the ectomesenchymal condensation (a process in which the epithelial bud propagates into the ectomesenchyme), the density of the cells increases near the epithelial outgrowth. This condensation is owed to the increased mitotic activity carried in the cells of the tooth bud and mesenchymal cells surrounding it. These buds develop at the distal side of the dental lamina and each bud represents a group of cells at dental lamina's end. The epithelial part is separated from the mesenchyme by a basement membrane. The ectomesenchyme surrounding the tooth bud is called the dental *follicle or sac* whereas the area directly subjacent to the condensation is called the *dental papilla*. The dental follicle is ultimately responsible for the formation of cementum, periodontal ligament (PDL), and alveolar bone. The dental papilla is responsible for the formation of dental pulp and dentin.

1.1.2 Key Identifying Features

The enamel organ at this stage appears roughly ovoid to spherical with poor histodifferentiation and morphodifferentiation. A typical tooth bud consists of centrally located polygonal (multiple-shaped) cells and peripherally arranged columnar cells.

1.1.3 Clinical Significance

The successful development of the tooth depends on the interaction of epithelial and mesenchymal components. If these parts grow individually, neither will differentiate further [1]. This epithelial–mesenchymal interaction starts in the bud stage; therefore, any problem affecting the bud stage could seriously affect the development of teeth.

1.2 Cap Stage

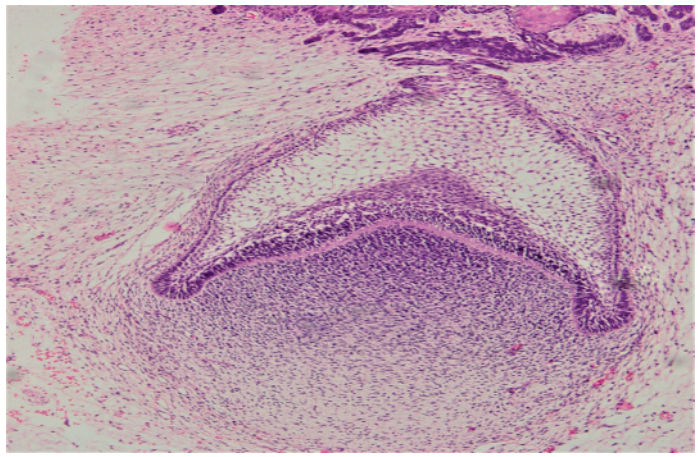

Figure 1.4 H and E stained section showing the cap stage of tooth development.

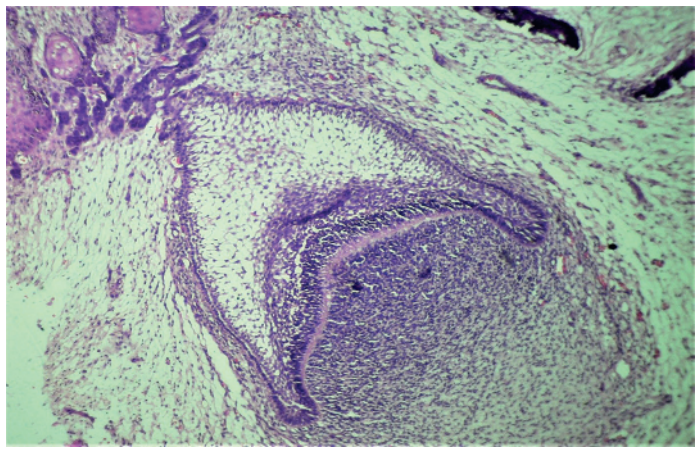

Figure 1.5 H and E stained section showing the cap stage of tooth development.

1.2.1 Description

The cap stage is the second stage of tooth development. As the tooth bud matures, it takes part of dental lamina along with it, which is called the lateral lamina. The tooth bud grows non-uniformly, and the growth is more in certain areas and less in others. This stage is called the cap stage as the epithelial outgrowth looks like a cap which is sitting on top of the condensed ectomesenchyme (dental papilla). During this stage, greater differentiation is seen in the central and peripheral cells. The central polygonal cells change into the stellate reticulum cells which have a somewhat star-shaped appearance due to greater intake of water, pushing the cells apart but retaining their desmosomal attachments. The peripheral cells change into external and inner enamel epithelium. The outer enamel epithelium cells are cuboidal whereas the inner epithelial cells are tall and columnar. These layers of epithelial cells are separated from the dental follicle and dental papilla by a basement membrane. Another structure called the *enamel knot* is formed during this stage which represents a collection of cells in the center of the inner enamel epithelium. It is a transitory structure which is believed to contribute cells to the *enamel cord (strand of cells)*.

1.2.2 Key Identifying Features

The enamel organ resembles a cap present on top of the dental papilla. The dental follicle and dental papilla become more recognizable during this stage compared to the bud stage.

1.2.3 Clinical Significance

It is believed that the blood supply of the tooth is established during the cap stage. The blood vessels first enter through the dental follicle, then move into the dental papilla [2]. Any disruptions during this stage could severely affect the vascular supply of the tooth and in turn, its maturation, vitality, and eruption.

1.3 Early Bell Stage

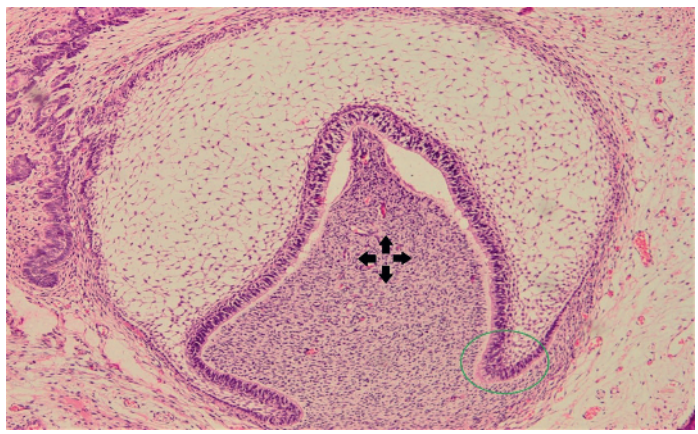

Figure 1.6 H and E stained section showing the early bell stage of tooth development (green circle, cervical loop; arrows, dental papilla).

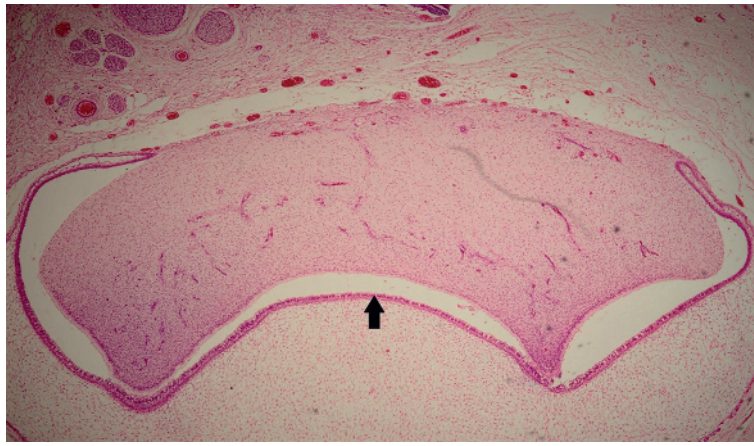

Figure 1.7 H and E stained section showing the early bell stage of tooth development (arrow, dental follicle).

1.3.1 Description

During this stage, the enamel organ resembles a bell. It is during this stage that the tooth crown will undertake its final shape (morphodifferentiation) and ameloblasts along with odontoblasts are histodifferentiated. The region where the outer and inner enamel epithelial cells meet at the border of enamel organ is called the *cervical loop*. In between the stellate reticulum and the inner enamel epithelial cells, some of the cell population differentiates and forms a new layer of cells called *stratum intermedium*. The cells of the inner enamel epithelium and stratum intermedium work collaboratively to form the enamel tissue. The enamel organ during the early bell stage clearly shows its four diverse layers: outer enamel epithelium, inner enamel epithelium, stellate reticulum, and stratum intermedium. During this stage, the enamel organ loses its contact with the oral epithelium as the dental lamina is broken down. This connection is restored during the process of tooth eruption. The remnants of dental lamina are called epithelial rest of Serres. In the early bell stage, the enamel knot disappears and the enamel cord appears between the stratum intermedium and stellate reticulum.

1.3.2 Key Identifying Features

On histological sections, bell-shaped enamel organ dissociated from the oral epithelium can be seen clearly. The tooth germ during this stage is enclosed by dental follicle. The cervical loop is also very prominent and easily recognizable.

1.3.3 Clinical Significance

Many important structures appear during this stage. It is believed that enamel cord facilitates the change from the cap to bell stage [1]. The cervical loop is responsible for the formation of Hertwig's epithelial root sheath (HERS) [3].

1.4 Late Bell Stage

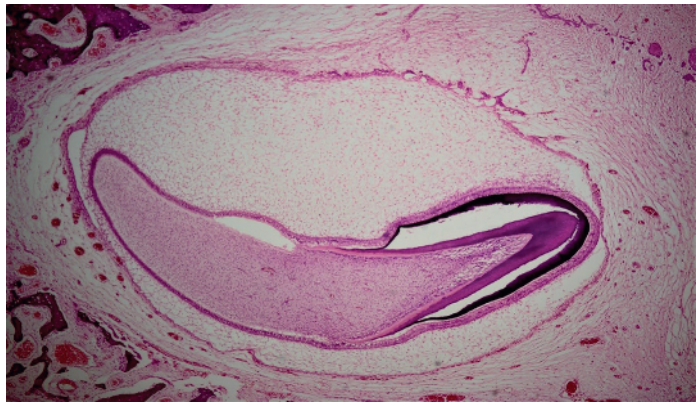

Figure 1.8 H and E stained decalcified section showing the late bell stage of tooth development.

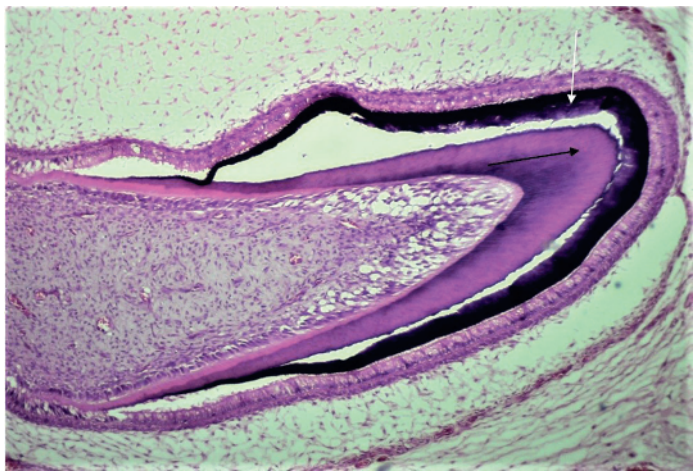

Figure 1.9 H and E stained decalcified section showing the late bell stage of tooth development (white arrow, enamel; black arrow, dentin).

1.4.1 Description

In the late bell stage, the tooth germ increases in size, and the hard tissues of the teeth start forming. The process of dentin formation is called *dentinogenesis* and it always precedes the process of enamel formation, i.e. *amelogenesis*. It is beyond the scope of this book to go into details of these processes but briefly, under the influence of inner enamel epithelium (which changes into pre-ameloblasts), the adjacent peripheral cells of dental papilla become odontoblasts. These odontoblasts start secreting of pre-dentin followed by dentin; this secretion stimulates pre-ameloblasts to change into ameloblasts which start secreting the enamel matrix (which mineralizes and becomes dental enamel later). While secreting, odontoblasts move away from the secretion area, leaving behind their odontoblastic processes. Similarly, ameloblasts migrate away from dentin while

secreting enamel matrix. It should be noted that the formation of these two tissues begins in the area of future cusps/incisal edges and then slopes downward. This is the stage where the commencement of root formation begins as well.

1.4.2 Key Identifying Features

On the histological sections, prominently visible dental hard tissues (enamel and dentin) can be seen. Ameloblasts (on top of the newly formed enamel) and odontoblasts (just below the newly formed dentin) are also evident.

1.4.3 Clinical Significance

The visible development of HERS begins during this stage. The HERS is responsible for determining the shape, size, and number of roots [4]. Disruption to this stage could affect amelogenesis and dentinogenesis, leading to the formation of abnormal enamel and dentin, respectively (or non-formation) [5].

1.5 Root Formation

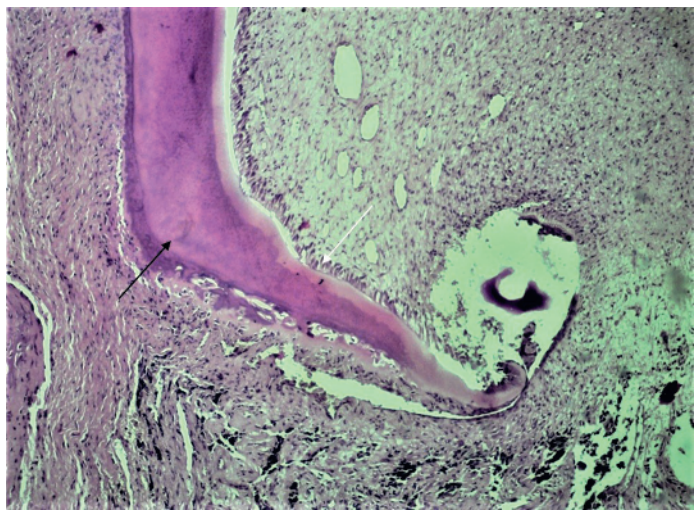

Figure 1.10 H and E stained section showing a tooth's root formation (white arrow, odontoblasts; black arrow, dentin).

1.5.1 Description

The tooth root has many important functions including anchorage of the tooth in maxilla/mandible and facilitating provision of blood supply (through apical foramina). The inside of the root is composed of radicular dentin and pulp canals whereas, on the outside, it is covered by a thin calcified layer of cementum. Root formation occurs because of the interaction between HERS, dental papilla, and dental follicle. After crown formation, the cervical loop grows

apically as HERS circling dental papilla. The ectomesenchymal cells of dental papilla near the HERS change into odontoblasts and start secreting radicular dentin. The root dentin comes in contact with the dental follicle due to the perforation of HERS which leads to its mesh-network appearance. This contact changes dental follicular cells into cementoblasts (forming cementum), fibroblasts (forming PDL), and osteoblasts (forming alveolar bone). It should be noted that the HERS only maps the shape of the root and then disintegrates. Its remnants are known as epithelial cell rests of Malassez.

1.5.2 Key Identifying Features

On histological sections, developing root with prominent radicular dentin can be clearly seen just below a complete crown.

1.5.3 Clinical Significance

The HERS is responsible for determining the number of roots by forming a pair of tongue-shaped extensions that fuse [6]. Root formation plays an important role in tooth eruption. It is believed that with the pressure of the developing root, the crown of the tooth starts moving vertically to erupt in the oral cavity [7]. It should be noted, however, that there is evidence for rootless teeth to erupt [8] suggesting that it is a multifactorial process where root formation has a role, but it is not the only mechanism involved.

1.6 Amelogenesis Imperfecta (AI)

Figure 1.11 Low-power view of a ground section of a deciduous incisor showing irregular enamel surface (arrows) related to AI.

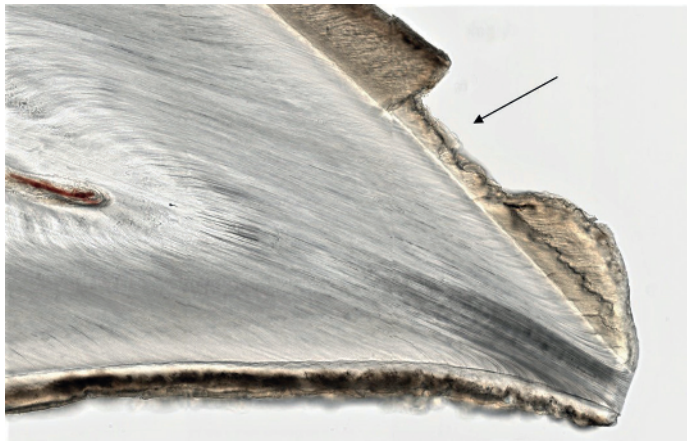

Figure 1.12 High-power view of a ground section of a deciduous incisor showing enamel pitting (arrow) related to AI.

1.6.1 Description

Amelogenesis imperfecta (AI) refers to a group of inherited genetic alterations that result in a defective enamel structure. AI is usually not associated with any syndrome or systemic disease. The teeth could appear yellow, brown, or sometimes grey. Several classifications have been suggested in the literature with the most commonly used one dividing AI into hypoplastic, hypomatured, and hypocalcified types. The hypoplastic type has insufficient amount of enamel matrix, the hypomature type has defective maturation of enamel whereas the hypocalcified type shows insufficient calcification of enamel. The genetic abnormalities in AI usually affect amelogenin (AMELX), enamelin (ENAM), kallikrein (KLK4), and matrix metalloproteinase 20 (MMP-20) genes. AI poses a significant clinical problem affecting the oral hygiene, masticatory function, and quality of life of the patient.

1.6.2 Key Identifying Features

On histological sections, it is difficult to identify the exact type of AI. However, reduced width/length of enamel along with pitting or clefts can be identified (ground sections) in addition to residual uncalcified enamel matrix (decalcified sections).

1.6.3 Clinical Considerations

Hypoplastic type is most common type of AI (60–73%) followed by hypomatured (20–40%) and hypocalcified (7%) types [9]. AI usually affects all the teeth of an individual and the diagnosis usually involves family history and clinical observation [10]. Radiographs reveal less than opaque enamel, especially when the mineralization has been affected [10]. The affected teeth are more prone to dental caries, dentinal sensitivity, and attrition [6]. Treatment options include masking of defective teeth with veneers and extra-coronal restorations [11].

1.7 Dentinogenesis Imperfecta (DI)

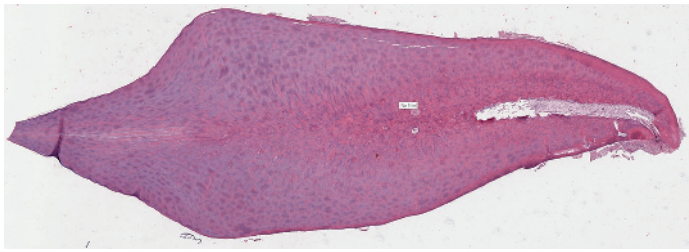

Figure 1.13 H and E stained decalcified section showing DI.

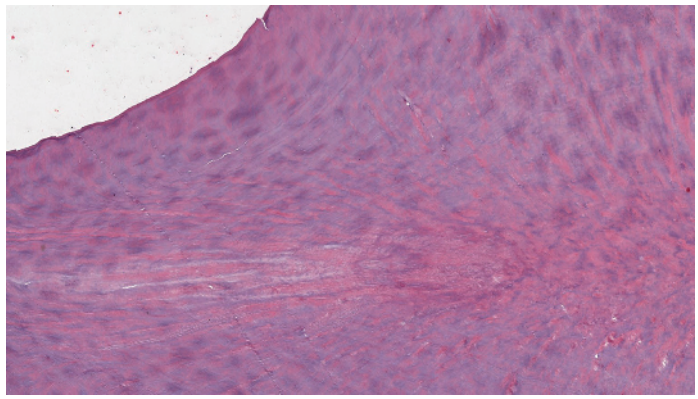

Figure 1.14 H and E stained decalcified section showing DI with a haphazard tubular architecture.

1.7.1 Description

Dentinogenesis imperfecta (DI) is a developmental hereditary condition (autosomal dominant) that affects the developing dentin. The dentin appears opalescent affecting both primary and permanent dentitions. DI can be classified into three main types: type I: DI associated with osteogenesis imperfecta; type II: DI similar to type I but not associated with osteogenesis imperfecta; and type III: initially reported in Brandywine population of Maryland and characterized by opalescent shell teeth (due to dentin hypotrophy) having marked attrition and large pulp chambers. As dentin forms the bulk of the tooth tissue, the teeth affected by DI are weak and prone to breakage and wear.

1.7.2 Key Identifying Features

On histological sections, teeth affected by DI show irregular dentinal tubules. In some areas, dentinal tubules can be completely absent. The dentin present can be quite irregular and haphazard and the pulp chamber can be quite small or completely obliterated.

1.7.3 Clinical Considerations

DI affects both dentitions and has an incidence of 1 in 6000 people [12]. The teeth have an amber color that ranges from yellow to brown or from blue to gray [13]. The normal scalloped interdigitation of dentin with enamel does not exist, and the flat enamel dentin junction leads to cracking of

enamel followed by attrition of dentin [14]. The diagnosis is usually based on family history and the radiographical and clinical appearance of the teeth. Radiographically, the teeth usually have bulbous crowns with obliterated pulp chambers [12]. Clinically, the teeth are discolored with visible clinical defects and fractured enamel [5]. Treatment modalities include prosthetic crowns, over-dentures, orthodontic treatment (depending upon the severity), and dental implants (when all other conservative approaches have failed [12, 15]).

1.8 Dentin Dysplasia (DD)

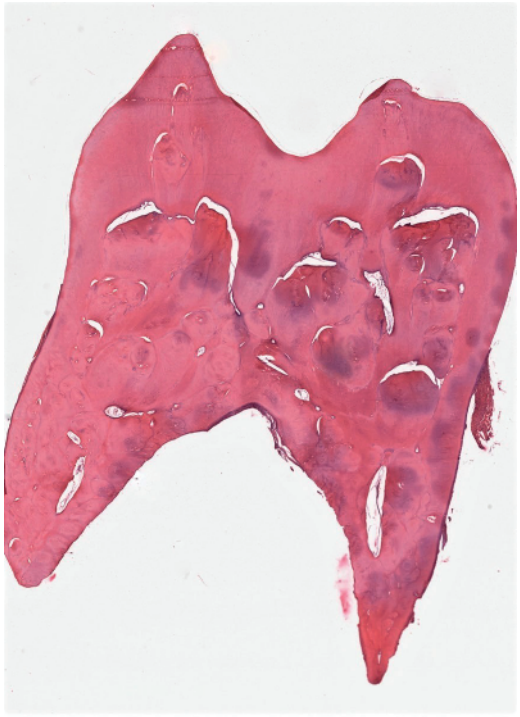

Figure 1.15 H and E stained decalcified section showing DD with haphazard coalescent globules of dentin and pulpal obliteration.

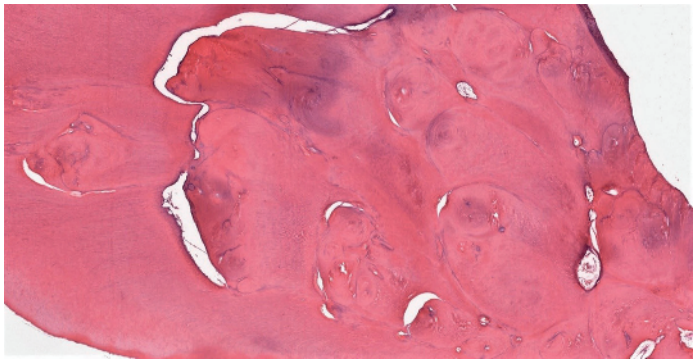

Figure 1.16 H and E stained decalcified section showing DD with the typical "water around the boulders" appearance.

1.8.1 Description

Dentin dysplasia (DD) is a rare genetic disorder that affects the development of dentin, mostly in radicular area. It can affect both dentitions, where the teeth have normal enamel but abnormal dentin with atypical pulp morphology. The first classification of DD was put forward by Witkop in the 1970s with DD divided into two types: DD-1 (radicular type) and DD-2 (coronal type) [16]. The teeth affected by DD-1 present with short, blunt roots with obliterated pulp chambers. In DD-2, teeth present with discoloration (brown to blue, amber colored, or opalescent), normal roots but enlarged pulp chambers (thistle tube appearance). The pulp chambers of primary teeth in DD-2 are almost completely obliterated whereas in permanent teeth, they may be partially obliterated.

1.8.2 Key Identifying Features

Histologically, irregular dentin with a disturbed tubular pattern, atubular areas, and globular atypical dentin masses inside pulp chambers can be seen.

1.8.3 Clinical Considerations

The etiology of this disease is still unclear. Wesley et al. previously proposed that it could be due to a problem with ameloblasts which leads to an abnormal differentiation of odontoblasts, leading to DD [17]. It was also proposed earlier that due to a problem with dental papilla (foci within it becoming calcified), DD develops as a result of less growth and/or obliteration of pulp chambers [18]. The diagnosis is based on clinical examination and radiographs. The teeth affected by DD have esthetic and functional abnormalities [19]. In addition, they are more prone to be mobile and are exfoliated prematurely [19]. The treatment options include stainless-steel crowns, endodontic therapy (although difficult due to obliteration of pulp chambers), removable dentures, and dental implants [20–22].

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