Chapter 1

Tooth Formation

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Teeth develop from epithelial cells from the mucosal lining of the oral cavity and cranial neural crest-derived ectomesenchymal cells. These latter cells originate at the ectodermal/neuroectodermal junction of the developing brain, extending rostrally from the caudal boundary of the hindbrain and neural tube to the midbrain and caudal forebrain. They give rise to most connective tissues in the craniofacial region including the bones of the calvarium, face, and jaws. Since these bones that are formed by mesenchymal cells have an ectodermal/neuroectodermal ancestry, they are also known as ectomesenchyme [4–7].

The process of tooth formation starts with the formation of the dental lamina, a sheet of epithelial cells extending from the lining of the oral cavity into the underlying ectomesenchyme. In this dental lamina, focal bud-like thickenings determine the sites of the future teeth, 20 for the deciduous dentition and 32 for the permanent one, and together with a surrounding aggregation of ectomesenchymal cells they represent the earliest stage of the tooth germ (Figs. 1.1a, 1.2).

Subsequently, the epithelial bud transforms into a cap and from that point on is called enamel organ. Due to the formation of a concavity along the inner surface, the cap transforms into a bell. Ectomesenchymal cells lying within this concavity form the dental papilla that will become the dental pulp, the soft tissue core of the teeth. Other ectomesenchymal cells surround the enamel organ and form the dental follicle, the fibrous bag that invests the tooth germ and separates it from the adjacent jaw bone. Within the bell-shaped enamel organ, three different components are discerned: the inner enamel epithelium facing the dental papilla, the outer enamel epithelium lying adjacent to the dental follicle, and the intervening loose stellate epithelium that is called the stellate reticulum (Figs. 1.1b, 1.3).

From the bell stage onwards, reciprocal inductive events take place causing inner enamel epithelium and adjacent dental papilla cells to develop into enamel-forming ameloblasts and dentin-producing odontoblasts. The differentiation of dental papilla cells into odontoblasts

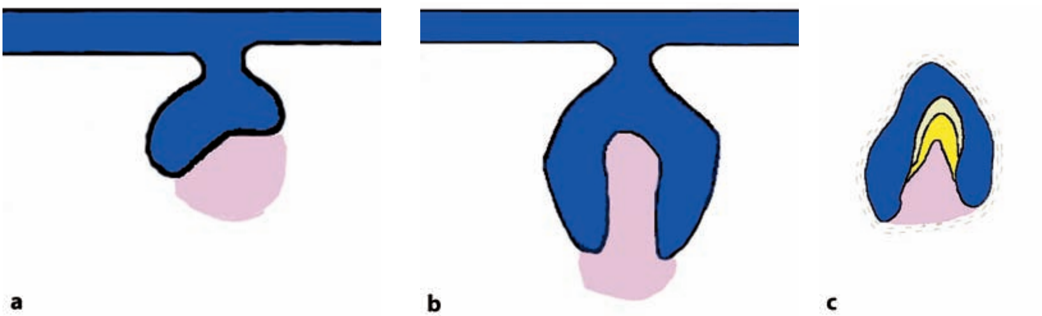

Fig. 1.1a–c Diagram showing consecutive stages of early tooth formation. **a** Bud stage, **b** Cap stage, and **c** Bell stage. Epithelium shown in *blue*, ectomesenchyme in *pink*, dentin in *yellow*, and enamel in *grey*

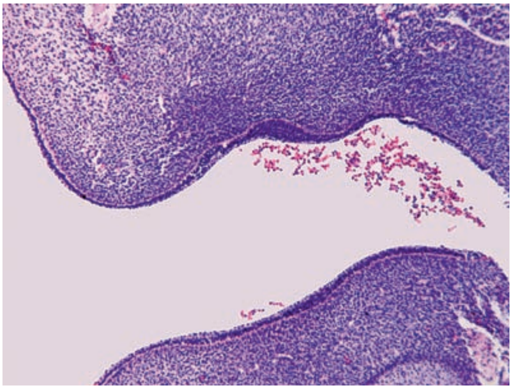

Fig. 1.2 Epithelial thickening of oral epithelium with underlying ectomesenchyme

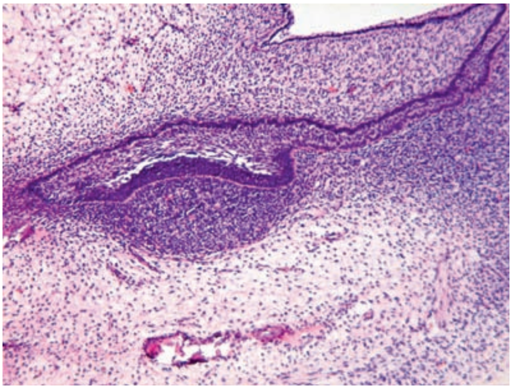

Fig. 1.3 Cap stage of tooth germ showing enamel organ composed of loose stellate reticulum bordered by inner enamel epithelium facing the ectomesenchymal condensation that will develop into the dental papilla (see Fig. 1.4)

requires a stimulus from the inner enamel epithelium, whereas the terminal differentiation of inner enamel epithelium into enamel-producing ameloblasts cannot occur without the presence of dentin. Therefore, dentin production occurs before enamel production and this is recapitulated in some odontogenic lesions that may display dentin formation but no enamel production, whereas the converse is never seen.

The odontoblasts form a matrix of collagen fibres called predentin that subsequently calcifies to become dentin. During dentinogenesis, odontoblasts recede from the dentino-enamel junction leaving a cytoplasmic extension behind in the deposited dentinal matrix. This explains why dentin has a tubular architecture, each dentinal tubule containing the cytoplasmic process of a single odontoblast (Figs. 1.1c, 1.4a, b).

Deposition of enamel starts after a tiny amount of dentin has been formed at the interface between future ameloblasts and odontoblasts. The enamel matrix subsequently calcifies to consist of approximately 95% minerals. This high mineral content explains why it does not withstand decalcification needed for histology.

While ameloblasts and odontoblasts are depositing enamel and dentin, inner and outer enamel epithelial cells join and proliferate in a downward way to encircle an increasing part of the dental papilla, thus creating a tube that maps out the form and size of the root of the teeth. This epithelial cuff is known as the epithelial root sheath or root sheath of Hertwig. In this root sheath, the inner enamel epithelium does not differentiate into enamel producing ameloblasts anymore but still induces the dental papilla cells to become odontoblasts that have to form the root dentin (Figs. 1.5, 1.6). Thereafter, Hertwig's root sheath fragmentates. In this way, ectomesenchymal cells from the dental follicle gain access to the root surface. These cells differentiate into cementoblasts and secrete cementoid on the surface of the intermediate cementum laid down before by them as an initial layer. Cementoid calcifies to become cementum. Whether cells from Hertwig's root sheath also contribute to initial cementum formation is controversial [1, 3, 8].

Besides the formation of cementum, dental follicle ectomesenchymal cells are also responsible for the formation of the other periodontal tissues: parts of the bony alveolar socket and the collagenous periodontal ligament that connects the tooth with this socket.

Remnants of Hertwig's root sheath form a permanent component of the periodontal ligament; they are known as rests of Malassez and are the source of some cystic jaw lesions. Moreover, these epithelial rests probably play a role in preventing contact between root surface and alveolar socket bone, thus ensuring preservation of tooth mobil-

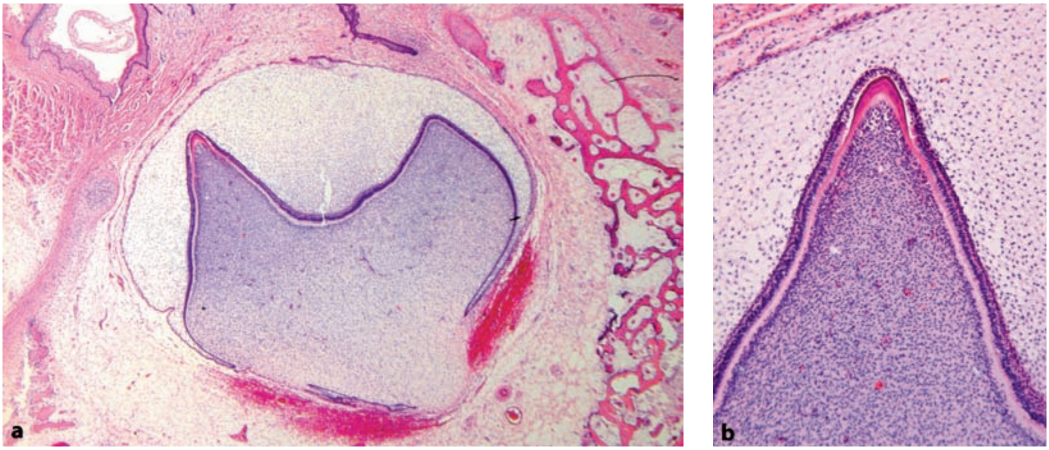

Fig. 1.4 **a** Bell stage of tooth germ. **b** At the tip of the dental papilla, deposition of enamel (*purple*) and dentin (*pink*) has started

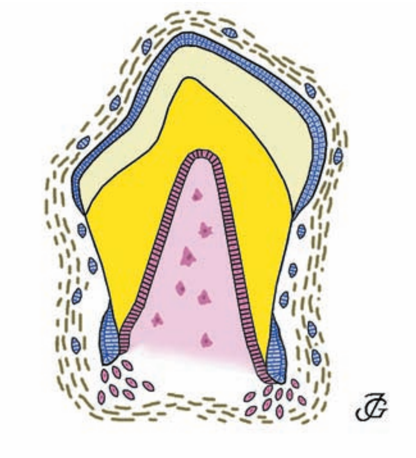

Fig. 1.5 Tooth germ in its late development. The crown is completely formed. The root is still growing at its apical tip, cells from the dental papilla being recruited to become dentin-forming odontoblasts. At this site, inner enamel epithelium still induces development of odontoblasts with subsequent dentin formation, but the subsequent differentiation of epithelium into ameloblasts forming enamel does not take place in root formation. (Drawing by John A.M. de Groot)

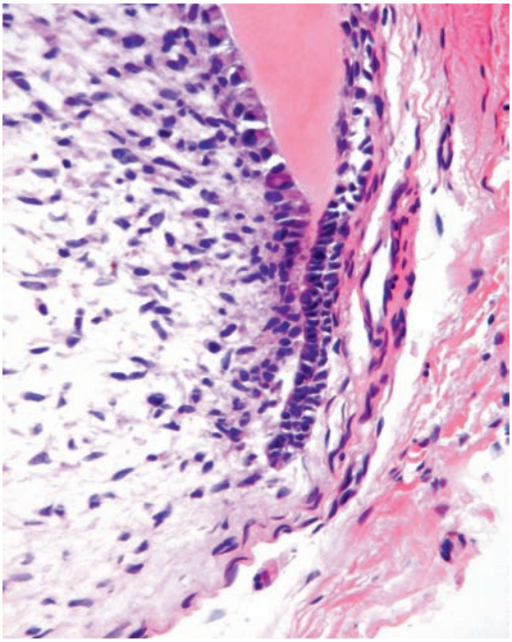

Fig. 1.6 Apical part of tooth germ showing Hertwig's epithelial root sheath. Cylindrical odontoblasts form dentin adjacent to the basal side of the opposing inner enamel epithelium

ity and inhibiting root resorption [2]. Other epithelial reminiscencies to the tooth development lie more superficially in the jaw tissues; they are the epithelial rests of Serres, which originate from the dental lamina.

When the formation of the crown is complete, the enamel organ atrophies. The stellate reticulum disappears and inner and outer enamel epithelium form an epithelial covering of the tooth crown—the so-called reduced enamel epithelium—which remains present until the tooth erupts into the oral cavity. Fluid accumulation between enamel surface and this epithelial investment may give origin to cystic lesions.

In humans, tooth formation starts already at the 6th week of embryonic life. It continues until early adulthood when the roots of the permanent 3rd molars reach their completion. The various stages of tooth development are clearly displayed by jaw radiographs taken from children with a mixed dentition. These radiographs show fully formed deciduous teeth and permanent teeth in varying stages of development. One should realise that all above-described developmental stages may be observed in the jaw at one and the same time as odontogenesis takes place from early embryonic life until early adolescence. To mention just one example, inner and outer enamel epithelium may show active proliferation at the developing root tip while slightly more coronally, the root sheath dissolves and cementoblasts from the dental follicle are lying down cementum, both these events occurring within a distance of only 1 mm from each other at the developing root surface.

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