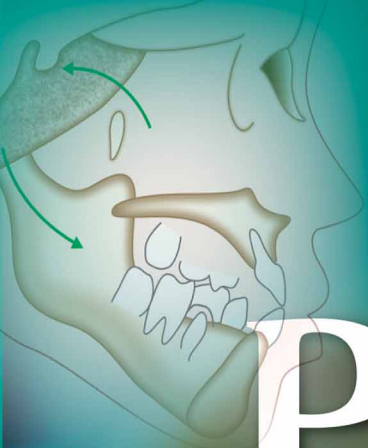
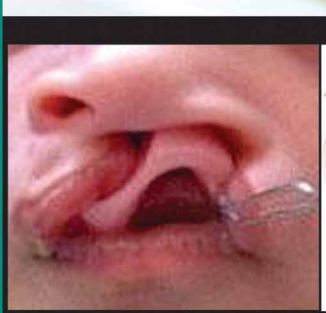
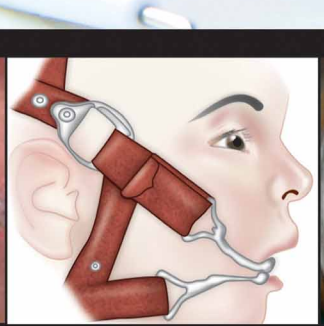
Manual of Pediatric Dentistry





Sridhar Premkumar







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- Discuss the characteristics and importance of young permanent teeth in children.
- Describe the importance of first permanent molar in pediatric dentistry.

Describe in detail about the development of teeth and its associated structures.

Development of the human tooth can be observed as early as the 6th week of embryonic life. The tooth bud (sometimes called the tooth germ) is an aggregation of cells, which eventually forms the tooth. These cells are derived from the ectoderm of the first branchial arch and the ectomesenchyme of the neural crest (Fig. 4.1).

The tooth bud or germ is organized into three parts (Fig. 4.2).

Enamel Organ

- The enamel organ is composed of the outer enamel epithelium, inner enamel epithelium, stellate reticulum and stratum intermedium
- These cells give rise to ameloblasts, which produce enamel and the reduced enamel epithelium

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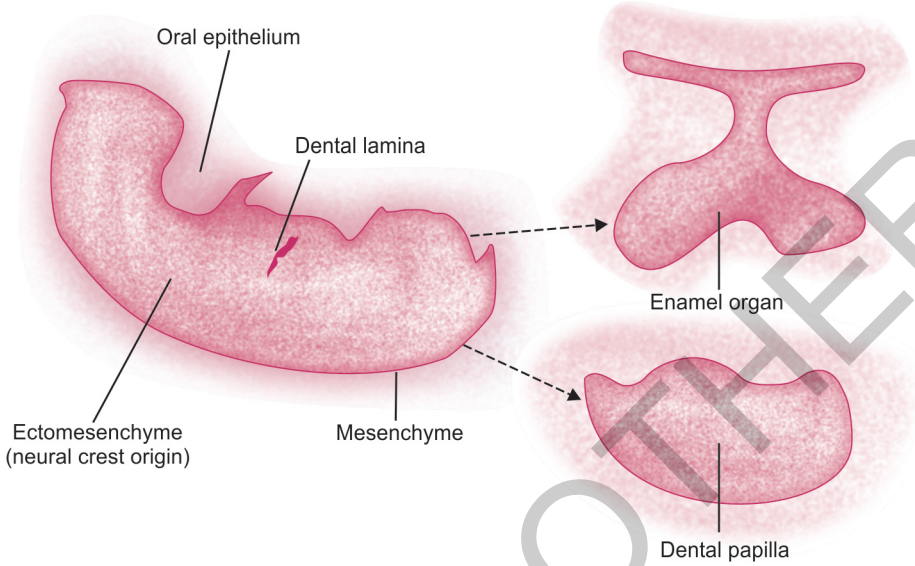

Fig. 4.1: Development of tooth bud

- The location where the outer enamel epithelium and the inner enamel epithelium join is called the cervical loop
- The growth of cervical loop cells into the deeper tissues forms Hertwig's epithelial root sheath (HERS), which determines the root shape of the tooth.

Dental Papilla

- The dental papilla contains cells that develop into odontoblasts, which are dentin-forming cells
- Additionally, the junction between the dental papilla and inner enamel epithelium determines the shape of the crown of the tooth
- Mesenchymal cells within the dental papilla are responsible for the formation of the tooth pulp.

Dental Follicle or Dental Sac

- The dental follicle gives rise to three important entities: cementoblasts, osteoblasts and fibroblasts
- Cementoblasts form the cementum of the tooth
- Osteoblasts give rise to the alveolar bone around the roots of the teeth
- Fibroblasts develop the periodontal ligaments, which connect the teeth to the alveolar bone through the cementum.

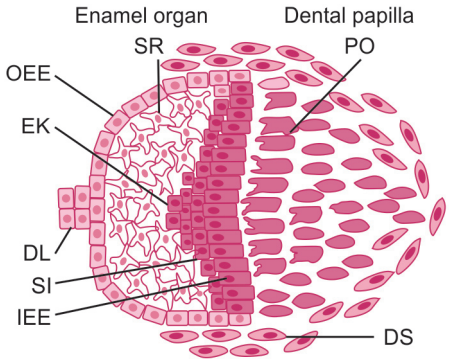

Fig. 4.2: Contents of tooth bud (OEE, outer enamel epithelium; IEE, inner enamel epithelium; EK, enamel knot; DS, dental sac; DL, dental lamina remnants; SR, stellate reticulum; SI, stratum intermedium; PO, preodontoblasts).

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Eventually, the enamel organ will produce enamel, the dental papilla will produce dentin and pulp and the dental follicle will produce all the supporting structures of a tooth.

Initiation (Bud Stage)

The initiation stage is first observed in the 6-week-old fetus. It is characterized by the appearance of the tooth bud without a clear arrangement of cells. The stage technically begins once epithelial cells proliferate into the ectomesenchyme of the jaw. The tooth bud itself comprises of the group of cells remaining at the end of the dental lamina.

Primary Teeth

- Cells in the basal layer of the oral epithelium proliferate at a more rapid rate than the adjacent cells
- This result in an epithelial thickening called 'primordium' in the region of the future dental arch that extends along the entire free margin of the jaws
- Primordium of the ectodermal portion of the teeth results in dental lamina (Fig. 4.3)
- At the same time, 10 round or ovoid swellings occur in each jaw in the position to be occupied by the primary teeth.

Permanent Teeth

- Cells of the basal layer, that contains the entire growth potential of the teeth, begin to proliferate at a more rapid rate than do the adjacent cells
- The permanent molars, like the primary teeth, arise from the dental lamina
- The permanent incisors, canines and premolars develop from the buds of their primary predecessors
- The congenital absence of a tooth is the result of a lack of initiation or an arrest in the proliferation of cells

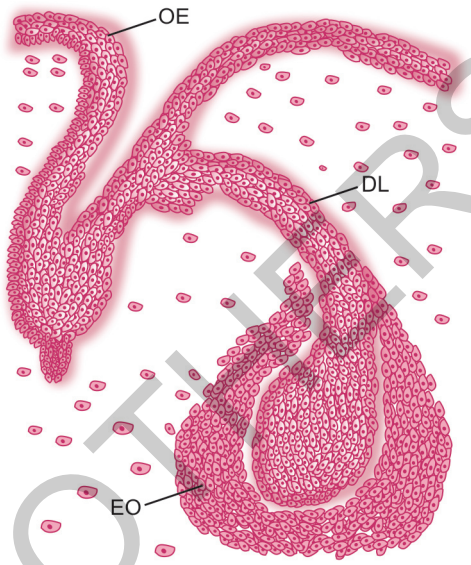

Fig. 4.3: Diagrammatic representation of initiation stage (OE, oral epithelium; DL, dental lamina; EO, enamel organ).

- The presence of supernumerary teeth is the result of a continued budding of the enamel organ.

Proliferation (Cap Stage)

- Proliferation of the cells continues during the cap stage resulting in an unequal growth in the different parts of the bud and a cap is formed
- The first signs of an arrangement of cells in the tooth bud occur in the cap stage
- A shallow invagination appears on the deep surface of the bud (Fig. 4.4)
- The peripheral cells of the cap later form the outer and inner enamel epithelium
- The degree of differentiation of the cells determines whether a cyst, an odontoma or a supernumerary tooth develops
  - Excessive proliferation of cells may result in epithelial rests, which may remain inactive or become

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activated as a result of an irritation or stimulus
- If the cells become partially differentiated or detached from the enamel organ in their partially differentiated state, they assume the secretory functions common to all epithelial cells and a cyst develops
- If the cells become more fully differentiated or detached from the enamel organ, they produce enamel and dentin, which results in an odontoma or a supernumerary tooth.

Histodifferentiation and Morphodifferentiation (Bell Stage)

During the bell stage, the dental lamina disintegrates, leaving the developing teeth completely separated from the epithelium of the oral cavity; the two will not join again until the final eruption of the tooth into the oral cavity.

- The epithelium continues to invaginate and deepen until the enamel organ takes on the shape of a bell (Fig. 4.5) and the majority of its cells are called the stellate reticulum because of their star-shaped appearance
- Cells on the periphery of the enamel organ separate into three important layers:
  - Cuboidal cells on the periphery of the dental organ are known as the outer enamel epithelium
  - The columnar cells of the enamel organ adjacent to the dental papilla are known as the inner enamel epithelium
  - The cells between the inner enamel epithelium and the stellate reticulum form a layer known as the stratum intermedium
- The rim of the dental organ, where the outer and inner enamel epithelium join is called the cervical loop
- In this stage, there is a differentiation of the cells of the dental papilla into odontoblasts and of the cells of the inner enamel epithelium into ameloblasts
- Histodifferentiation marks the end of the proliferative stage as the cells lose their capacity to multiply
- Disturbances in the differentiation of the formative cells of the tooth germ result in abnormal structure of the dentin or enamel, e.g. amelogenesis or dentinogenesis imperfecta.

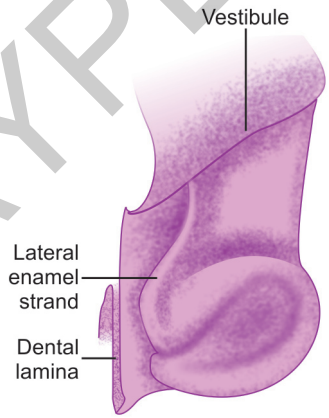

Fig. 4.4: 3D diagrammatic representation of cap stage

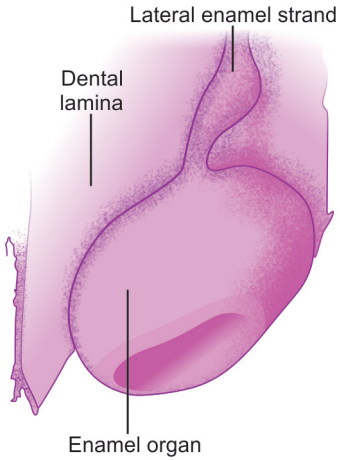

Fig. 4.5: 3D diagrammatic representation of bell stage

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In the morphodifferentiation stage, the formative cells are arranged to outline the form and size of the tooth.

- The morphologic pattern of the tooth becomes established when the inner enamel epithelium is arranged so that the boundary between it and the odontoblasts outlines the future dentinoenamel junction (DEJ)
- Disturbances and aberrations in morphodifferentiation lead to abnormal forms and sizes of teeth, e.g. peg teeth, microdontia and macrodontia.

Apposition (Advanced Bell Stage)

In prior stages, all of the inner enamel epithelium cells were dividing to increase the overall size of the tooth bud, but rapid division called mitosis stops during this stage at the location, where the cusps of the teeth form.

1. Appositional growth is the result of a layer-like deposition of a non-vital extracellular secretion in the form of a tissue matrix.
2. Hard tissues, including enamel and dentin, develop during this stage of tooth development.
3. The formative cells deposit the enamel and dentin matrix according to a definite pattern and at a definite rate (Fig. 4.6):
   a. The inner enamel epithelial cells change in shape from cuboidal to columnar.
   b. The nuclei of these cells move closer to the stratum intermedium and away from the dental papilla.
   c. The adjacent layer of cells in the dental papilla suddenly increases in size and differentiates into a layer of odontoblasts, which are the cells that form dentin. Odontoblasts would not form, if it was not for the changes occurring in the inner enamel epithelium.

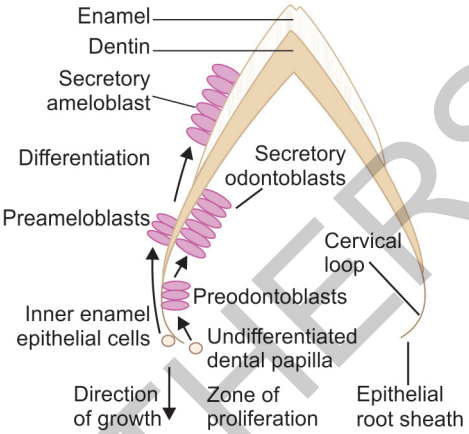

Fig. 4.6: Diagrammatic representation of apposition stage

   d. As the changes in the inner enamel epithelium and the formation of odontoblasts continue from the tips of the cusps, the odontoblasts secrete a substance, an organic matrix, into their immediate surroundings, the organic matrix contains the material needed for dentin formation.
   e. As odontoblasts deposit organic matrix, they migrate towards the center of the dental papilla.
   f. Thus, unlike enamel, dentin starts forming in the surface closest to the outside of the tooth and proceeds inward.
   g. Cytoplasmic extensions are left behind as the odontoblasts move inward. The unique, tubular microscopic appearance of dentin is a result of the formation of dentin around these extensions.
   h. After dentin formation begins, the cells of the inner enamel epithelium secrete an organic matrix against the dentin. This matrix immediately mineralizes and becomes the tooth's enamel. Outside the dentin are ameloblasts, which are cells that continue the process of enamel formation;

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therefore, enamel formation moves outwards, adding new material to the outer surface of the developing tooth.

4. Any systemic disturbance or local trauma that injures the ameloblasts during enamel formation can cause an interruption or an arrest in matrix apposition, e.g. enamel hypoplasia.

Calcification

- Calcification (mineralization) takes place following matrix deposition and involves the precipitation of inorganic calcium salts within the deposited matrix
- The original nidus increases in size by the addition of concentric laminations
- These individual calcospherites are eventually approximated or fused into a homogeneously mineralized layer of tissue matrix
- If the calcification process is disturbed, there is a lack of fusion of the calcospherites. These deficiencies are referred to as interglobular dentin.

Early Development and Calcification of the Anterior Primary Teeth

- The first macroscopic indication of morphologic development occurs at approximately 11 weeks in utero—**Kraus and Jordan** (Table 4.1)
- The maxillary and mandibular central incisor crowns appear identical at this early stage as tiny, hemispheric, mound-like structures

Table 4.1: Early development of the anterior primary teeth

Primary tooth	Macroscopic appearance
Central incisors	11 weeks in utero
Lateral incisors	13–14 weeks in utero
Canines	14–16 weeks in utero

- Calcification of the central incisor begins at approximately 14 weeks in utero, with the maxillary central incisor slightly preceding the lower central
- The initial calcification of the lateral incisor occurs at 16 weeks and of the canine at 17 weeks.

Early Development and Calcification of the Posterior Primary Teeth

Refer Table 4.2.

Dentinogenesis

- Dentin formation known as dentinogenesis (Fig. 4.7), is the first identifiable feature in the crown stage of tooth development
- The formation of dentin must always occur before the formation of enamel
- Odontoblasts, the dentin-forming cells, differentiate from cells of the dental papilla
- They begin secreting an organic matrix around the area directly adjacent to the inner enamel epithelium, closest to the area of the future cusp of a tooth

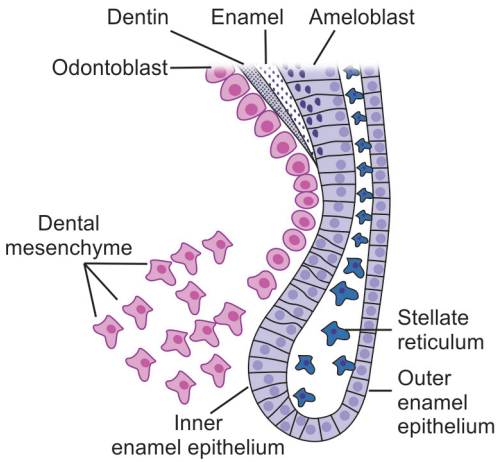

Fig. 4.7: Amelogenesis and dentinogenesis

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Table 4.2: Early development and calcification of the posterior primary teeth

Primary tooth	Macroscopic appearance	Time of apex of mesiobuccal cusp calcification	Calcification level at birth
Maxillary 1st molar	12½ weeks in utero	15½ weeks in utero	Three fourth of the occlusal gingival height of the crown
Maxillary 2nd molar	12½ weeks in utero	19 weeks in utero	One fourth of the occlusal gingival height of the crown
Mandibular 1st molar	12 weeks in utero	15½ weeks in utero	Completely calcified cap covers the occlusal surface
Mandibular 2nd molar	12½ weeks in utero	18 weeks in utero	Small area of uncalcified tissue remains in the middle of the occlusal surface; smooth occlusal surface, sharp conical cusps and angular ridges

- The organic matrix contains collagen fibers
- The odontoblasts begin to move towards the center of the tooth, forming an extension called the odontoblast process
- The odontoblast process causes the secretion of hydroxyapatite crystals and mineralization of the matrix.

Amelogenesis

- Enamel formation is called amelogenesis (Figs 4.8A to F) and occurs in the crown stage of tooth development
- Reciprocal induction governs the relationship between the formation of dentin and enamel; dentin formation must always occur before enamel formation
- Generally, enamel formation occurs in two stages—the secretory and the maturation stages:
  - Proteins and an organic matrix form partially mineralized enamel in the secretory stage
  - The maturation stage completes enamel mineralization.

Secretory Stage

- In the secretory stage, ameloblasts release enamel proteins that contribute to the enamel matrix, which is then partially mineralized by the enzyme alkaline phosphatase
- The appearance of this mineralized tissue, which usually occurs around the 3rd or 4th month of pregnancy, marks the first appearance of enamel in the body
- Ameloblasts deposit enamel at the location of the future cusps of the teeth alongside the dentin
- Enamel formation then continues outward, away from the center of the tooth.

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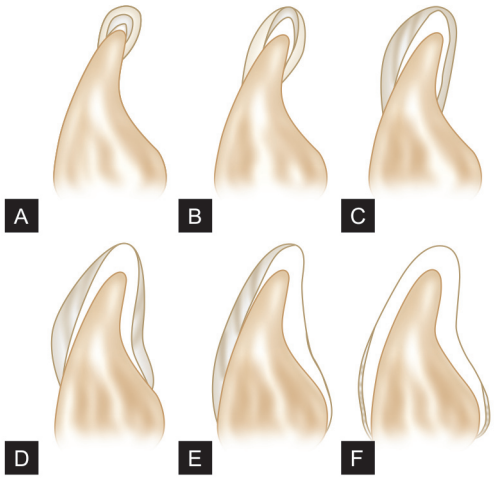

Figs 4.8A to F: Process of enamel maturation

Maturation Stage

The process of maturation begins near the growth centers (at the cusp tips) and proceeds both from the DEJ towards the enamel surface and cervically along the DEJ (refer Figs 4.8A to F). In deciduous teeth, some enamel near the cervical line may still be immature when the tooth erupts.

- In the maturation stage, the ameloblasts transport some of the substances used in enamel formation out of the enamel
- Thus, the function of ameloblasts changes from enamel production, as occurs in the secretory stage to the transportation of substances
- Most of the materials transported by ameloblasts in this stage are proteins used to complete mineralization
- The important proteins involved are amelogenin, ameloblastin, enamelin and tuftelin. By the end of this stage, the enamel completes its mineralization.

Root Formation

1. The epithelial cells of the external and internal enamel epithelium from the cervical loop proliferate to form a double-layered HERS.
2. This sheath of epithelial cells grows around the dental papilla between the dental papilla and follicle, until it encloses all, but the basal portion of the papilla.
3. A thin rim of root sheath the epithelial diaphragm and encloses the primary apical foramen. As the inner enamel epithelial cells of the root sheath progressively enclose more and more of the expanding dental papilla, they initiate the differentiation of odontoblasts from the cells at the periphery of the dental papilla.
4. These cells eventually form the dentin of the root. In this way, a single-rooted tooth is formed.
5. Multirooted teeth form essentially in the same way, except that the primary apical foramen is divided into two or three apical foramen by tongues of epithelium growing towards each other hence dividing the single foramen.
6. Once the root sheath forms, it rapidly initiates root formation and then fragments. With the onset of root formation, the crown of the tooth grows away from the bony base of the crypt and it hence gets stretched.
7. Although active mitosis takes place, the continuous stretching of the root sheath causes it to fragment to a fenestrated network around the tooth and is seen as clusters of epithelial cells called the cell rests of Malassez.

Periodontium

The periodontium, which is the supporting structure of the tooth, consists of the cementum, periodontal ligaments, gingiva and the alveolar bone.

Formation of the Periodontal Ligament

- Cells from the dental follicle give rise to the periodontal ligament (PDL)

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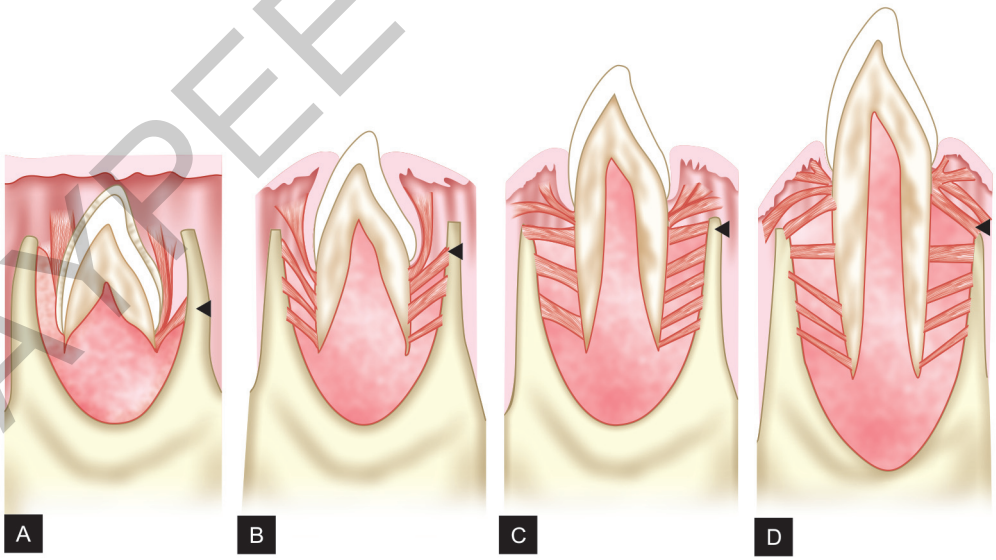
- Formation of the periodontal ligament begins shortly after the root formation from the fibroblasts of the dental follicle
- At an early stage of formation, the cells already have an oblique orientation and the fiber bundles they form also assume a similar orientation
- These fibroblasts secrete collagen, which interacts with fibers on the surfaces of adjacent bone and cementum
- This interaction leads to an attachment that develops as the tooth erupts into the mouth; the occlusion, continually affects the formation of periodontal ligament
- This perpetual creation of periodontal ligament leads to the formation of groups of fibers in different orientations, such as horizontal and oblique fibers
- Also before the tooth erupts, the crest of the alveolar bone is above the cementoenamel junction (CEJ) and the developing fiber bundles of the periodontal ligament are all directed obliquely
- Because as the tooth move during eruption, the level of alveolar crest comes to coincide with the CEJ and oblique fibers become horizontally aligned
- When the tooth finally comes into function, the alveolar crest is positioned near the apex
- The alveolar crest fibers have now become oblique again with a reversal in direction (Figs 4.9A to D).

Cementogenesis

Cementum formation is called cementogenesis and occurs late in the development of teeth.

- Cementoblasts are the cells responsible for cementogenesis
- Two types of cementum form are cellular and acellular
- Acellular cementum forms first
- The cementoblasts differentiate from follicular cells, which on reaching the surface of the tooth's root differ; HERS has begun to fragment at this time



Figs 4.9A to D: Development of principal fibers of periodontal ligament (◄). **A.** Initially oblique; **B.** Then horizontal; **C.** Horizontal; **D.** Then oblique again.

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- Once in contact with the HERS, they become large and assume all characteristics of a protein secreting cell and secrete fine collagen fibrils along the root surface at right angles, before migrating away from the tooth
- As the cementoblasts move, more collagen is deposited to lengthen and thicken the bundles of fibers
- Non-collagenous proteins, such as bone sialoprotein and osteocalcin, are also secreted, as mineralization takes place, the cementoblasts move away from the cementum and the fibers left along the surface eventually join the forming PDL
- Mineralization of the organic matrix occurs with deposition of hydroxyapatite crystals and this process is slow
- Due to this slow process the cementoblasts, which form the cementum retreat into the ligament, hence cementum is acellular
- Cellular cementum develops after most of the tooth formation is complete and after the tooth occludes (in contact) with a tooth in the opposite arch
- The cementoblasts forming cellular cementum become trapped in the cementum they produce.

Alveolar Bone

Alveolar process is the bone of the jaws, which contains the sockets or alveoli for the teeth. As root and cementum formation begin, bone is created in the adjacent area.

- Throughout the body, cells that form bone are called osteoblasts. In the case of alveolar bone, these osteoblasts cells form from the dental follicle
- The new bone is deposited around the developing ligament fiber bundles against the crypt wall
- The deposition of this bone gradually reduces the space between the crypt wall and tooth to the dimensions of the periodontal ligament
- Similar to the formation of primary cementum, collagen fibers are created on the surface nearest the tooth and they remain there until attaching to periodontal ligaments
- Like any other bone in the human body, alveolar bone is modified throughout life, osteoblasts create bone and osteoclasts destroy it, especially if force is placed on a tooth
- As it is the case when movement of teeth is attempted through orthodontics, an area of bone under compressive force from a tooth moving towards it has a high osteoclast level, resulting in bone resorption
- An area of bone receiving tension from periodontal ligaments attached to a tooth moving away from it has a high number of osteoblasts, resulting in bone formation.

Gingiva

The connection between the gingiva and the tooth is called the dentogingival junction. Information about formation of gingiva is not fully understood, but it is known that hemidesmosomes (attachment between epithelium and tooth) form between the gingival epithelium and the tooth and are responsible for the primary epithelial attachment.

- Hemidesmosomes provide anchorage between cells through small filament-like structures provided by the remnants of ameloblasts, the reduced enamel epithelium
- Once this occurs, junctional epithelium forms from reduced enamel epithelium and divides rapidly

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- This results in the perpetually increasing size of the junctional epithelial layer and the isolation of the remnants of ameloblasts from any source of nutrition
- As the ameloblasts degenerate, a gingival sulcus is created.

Nerve and Vascular Formation

Frequently, nerves and blood vessels run parallel to each other in the body and the formation of both usually takes place simultaneously and in a similar fashion. However, this is not the case for nerves and blood vessels around the tooth, because of different rates of development.

Nerve Formation

- Nerve fibers start to approach near the tooth during the cap stage of tooth development and grow towards the dental follicle
- Once there, the nerves develop around the tooth bud and enter the dental papilla when dentin formation has begun. Nerves never proliferate into the enamel organ.

Vascular Formation

- Blood vessels grow in the dental follicle and enter the dental papilla in the cap stage; groups of blood vessels form at the entrance of the dental papilla
- The number of blood vessels reaches a maximum at the beginning of the crown stage and the dental papilla eventually forms in the pulp of the tooth
- Throughout life, the amount of pulpal tissue in a tooth decreases, which means that the blood supply to the tooth decreases with age
- The enamel organ is devoid of blood vessels because of its epithelial origin and the mineralized tissues of enamel and dentin do not need nutrients from the blood.

Enumerate the dental anomalies that occur at different stages of tooth development.

- Refer Chapter 17 Congenital and Developmental Abnormalities in Children.

Discuss about deciduous teeth and its functions. Add a note on dental formulae.

- Primary teeth are called 'deciduous teeth'. Deciduous comes from the Latin word 'decidere' means 'to fall off'. The dentition that replaces primary dentition is called as 'secondary dentition' or 'adult dentition'.

Functions

- Mastication of food
- Support for the cheeks and lips maintaining a normal facial appearance and smile
- Formulation of clear speech
- Space maintenance for eruption of permanent teeth.

Dental Formulae

Primary Dentition

The number and type of teeth in each quadrant is described by the formula:

$$\text{Incisors } \frac{2}{2} \text{ Canines } \frac{1}{1} \text{ Molars } \frac{2}{2}$$

$$= \frac{\text{5 maxillary teeth per quadrant}}{\text{5 mandibular teeth per quadrant}}$$

Permanent Dentition

The number and type of teeth in each quadrant is described by the formula:

$$\text{Incisors } \frac{2}{2} \text{ Canines } \frac{1}{1} \text{ Premolars } \frac{2}{2} \text{ Molars } \frac{3}{3}$$

$$= \frac{\text{8 maxillary teeth per quadrant}}{\text{8 mandibular teeth per quadrant}}$$

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Discuss in detail about eruption of tooth. Add a note on chronology of eruption of teeth.

Refer Chapter 3 Development of Occlusion.

Teething problems and their management in children.

Teething

- The eruption of primary teeth usually begins around 4–8 months of age with the eruption of the lower incisors and is complete at around 30–36 months of age when second primary molars erupt
- The timing of tooth eruption varies by as much as 6 months
- The physiological process of tooth eruption is regulated by an array of genes, hormones and factors (Table 4.3).

Table 4.3: Factors regulating teething process

Factors	Examples
Genes	• *c-fos*
Hormones	• Pituitary growth hormone • Thyroid hormones • Parathyroid hormones
Growth factors	• Epidermal growth factor (EGF) • Colony-stimulating factor-1 (CSF-1) • Transforming growth factors-β1 (TGF-β1)
Cytokines	• Interleukin-1α (IL-1α) • Interleukin-1β (IL-1β) • Interleukin-10 (IL-10) • Tumor necrotizing factor-α (TNF-α)
Others	• Parathyroid hormone-related peptide (PTHrP) • Monocyte chemotactic protein-1 (MCP-1) • Immunoglobulin A (IgA)

Signs and Symptoms

Refer Table 4.4.

Teething Pain

- Teething pain, sometimes referred to as 'dentitio difficilis', is the commonest symptom associated with the eruption of the primary dentition
- Pain may result from elevation of inflammatory mediators in the crevicular fluid and in tissues surrounding the erupting tooth, which stimulate nociceptive receptors

Table 4.4: Signs and symptoms of teething

Systemic signs		Oral signs
• Agitation • Bowel upset including diarrhea, constipation, loose stool • Colic • Convulsive • Cough • Croup • Ear rubbing/pulling • Facial flushing • Fever • Loss of appetite • Malaise	• Malodorous urine • Otitis media • Respiratory problems including runny nose, congestion, throat infection • Restlessness • Severe crying • Skin rash • Sleep disturbance • Vomiting • Wakefulness • Weight loss	• Excessive saliva or drooling • Sucking of digits • Rubbing of gingiva • Inflamed/irritated gingiva • Painful gingiva/mouth • Perioral rash • Primary herpetic gingivostomatitis

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